Synthesis, Characterization and Optoelectronic Properties of Solar Cells Device for Vacuum Thermally Evaporated Pure and Gallium Doped CdSe Thin Films

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Abstract: Heterojunctions n-CdSe/p-Si, n-CdSe/P-Si and CdSe:Ga/p-Si have, through thermal evaporation, been based on P-type Si (002). Thin films with different doping ratios of 1, 3 and 5 wt percent are made. For the purpose of achieving optimal conditions the electrical and photovoltaic aspects of these films have been established. Solar cell quality is graduated. They were made of a vacuum heat evaporated mixture of CdSe and ga atoms to create a thin, p-Si single wafer film with a thickness of 3.5 μm and resistivity of 0.78 - 1.5 Ohm-cm² on R.T. They are then formed by n-CdSe/p-Si and n-CdSe(Ga)/p-Si heterojunctions. The density of the existing short circuit (jsc, open-circuit (Voc) and fill factor (ff)) and conversion rate of 40 mW/cm² (AM1) intensity. The efficiency of solar cells is calculated prior to and after a Ga dopant. The aim of this analysis was to determine characterization and optoelectronic characteristics of CdSe pure and gallium-doped solar cells in thin films. The result of this analysis under dark I-V conditions show good disciplinary behavior and an exponential relationship to the potential present bias. The calculation of the C-V suggested an abrupt form of heterozone diodes. The built-in potential Vbi is calculated and is found increasing after Ga-doping process. The built-in potential and the depletion width increases with increasing of Ga doping ratio.Solar cell conversion efficiency of n-CdSe/p-Si and n-CdSe:Ga/p-Si heterojunction properties were studied is found to be 5.25 % at 5 Wt% of Ga doping ratio. In conclusions, The I-V characteristic of Ga-doped CdSe solar cell thin film under the illumination conditions gives conversion efficiency of 5.25% at doping ratio 5%. This result of conversion is directly proportional to the Ga concentrations.

Keyword: n-CdSe:Ga/p-Si heterojunction, Solar cell, Open voltage circuit, Current circuit, Fill factor of solar cell.

1. Introduction: Cadmium Selenide (CdSe) is a promising material of thin film semiconductor II-VI compound due to its large absorption coefficients, a room temperature band gap of 1.74 eV and a high photo sensitivity. [1, 2]. Usually, CdSe is a n-type material are interested for their applications as photoconductors [3], solar cells [4,5], thin film transistors, gas sensors. The preparation of CdSe thin films by different methods have been used such as pulsed laser deposition technique, thermal, evaporation technique and spray deposition [6]. Ternary system of doped with other metal for increasing the short circuit current in the solar cell [7]. Investigations have also been made on the properties of CdSe devices with direct band gap of 1.74 eV device fabrications studied extensively. Mahawela et al [8] reported transparent thin films CdSe solar cells,
Murali et al. [9] studied photo-electrochemical solar cell. However, the effect of Ga-doping with CdSe by vacuum thermal evaporation technique at room temperature that is very limited [10]. The electrical and photovoltaic of both CdSe pure and that doped with Ga on Si heterojunctions have been prepared by vacuum thermal evaporation method, Ga-doping II-VI materials were reported [11, 12]. The effect of Ga Doping on GaSe:Ga/Si heterosexual features in relation to forward and reverse distortion voltages, and the effect of separate dopings on forward and reverse distinctions of dark current. In addition, The photocurrent (Iph) association with reverse bias voltage at different doping ratios. It indicates that the Ga doping ratio changes the short-circuit current and the open-circuit voltage. The authors use the cdse as n type and Si as p type to improve the electrical properties of the material [13]. The aim of this analysis was to determine how solar cells evaporated from the pure CdSe and gallium doped in thin films are to be described and optoelectronically proprietary.

2. Experimental Details: CdSe and CdSe:Ga alloys have been prepared using thermal evaporation technique to create the films with varying concentrations of 1, 3 and 5Wt %. Samples of CdSe and CdSe: Ga 1,3 and 5 % alloys were drawn up by direct mixing of the highly pure Cd and Se, as reported in the previous article, according to the atomic ratio of their constituents [14]. The contents were stored in quartz ampoules under 10-2torr base tension.. The ampoules were deposited inside furnace for 5 hours at a steady heating rate of 5o C/min according to a phase diagram of CdSe alloy [15]. The ampoule has continually been rocked to get a homogenous blend of the alloys during the heating process. The ampoules were broken down and the compound melted to powder extracted. The powder compound was used to create the films as a means of evaporation. The Si wafer also used the vacuum thermal evaporation process to deposit films from the doped CdSe and the cdSe.

3. RESULTS AND DISCUSSIONS

Characterization of CdSe and CdSe:Ga/Si Heterojunctions: The results of this study showed the optimum conditions are high concentration of CdSe NPs, absorption spectra to CdSe NPs for the range at the visible around (600±50)nm while Ps region at (λ =700nm) that means increasing in absorbance. The electrical properties characterizing heterojunction are typical of the current-voltage (I-V) and voltage-capacity (C-V). Indeed, these properties not only provide details on a heterozone band structure but also allow one to assess the utility of the unit. One of the reasons why CdSe and CdSe:Ga thin films are used in the technology of optoelectronic equipment is its strong electrical conductivity even without extrinsic doping [12].

Current-voltage (I-V) characteristics in the dark Conditions: The results of this study displays the current–voltage(I-V) curve of n-(CdSe and CdSe:Ga)/Si heterojunctions under dark condition in the forward and reverse directions at 300K(Fig.1). The efficiency of the device and all device parameters are very important to explain It. The dope Ga into CdSe increases the mobility of carries and to increase charge carries and to improve the electrical properties to reach the condition for solar cell [13].

Clearly, the current was steadily increased at reverse differences of voltage due to the rise in the probability of trapping because of trap centers and recombining at low tensile distances, which allows carriers to drift at a very low level. This current is known as recombination current which occurs at low voltages only[14]. It is
created by exciting each electron to retrieve the balance. The high voltage second region reflects a region of diffusion or bending, depending on the resistance. In this field, the bias voltage will provide enough energy to electrons to penetrate the barrier on both sides of the crossing. These observations agree with others[16]. Also, it was noticed that the heterojunction has very good correctional properties, very little current flow resistance in one direction and an exceptionally good resistance in the other direction with soft disintegration at an external distortion voltage of 0.2 V at a different doping ratio. This means that the heterojunction is anise type.

The lattice mismatch between CdSe and Si calculated by using Equation(1), where the lattice constant for Si equal to (a= 0.543 nm). The lattice mismatch was calculated to be (25.77%) for the deposited films.

\[
\Delta \text{e} = \frac{a_e}{2a} = \frac{a^2}{2|a_e - a_j|} \quad \ldots \ldots (1)
\]

**Fig. 1:** Shows the I-V function for CdSe and CdSe:ga)/Si heterojunction under forward and reverse ranges, the photocurrent highly depends on the biostrength observed to raise the current value at power density.

**Capacitance-voltage (C-V) Measurements:** The result obtained reverses the capacitance of the system with the voltage bias. The loss of the system capacitance (C) and the biasing voltage is induced by the expansion of the depletion layer (W), which increases the absorption region of the integrated potential (Vbi). This is a significant calculation as it defines various parameters such as the integrated potential (Vbi), capability of equipment and model of unit. Fig (2) offers heterojuncture (1/C2-V) measurements.
Fig. 2: $1/C^2$ versus bias voltage plot for $n$-(CdSe and CdSe:Ga)/Si heterojunction.

It is evident that the current produced by the gradual CdSe doped is more than pure (CdSe). This agrees with the theoretical treatment which dealt with these characteristics, and according to the following relation [17]. Table (1): shows the obtained results from the measurement of CdSe films. Results show that the device is "abrupt" The relationship between $1/C^2$ and reverse bias is confirmed to be straight line[9]. The integrated potentials ($V_{bi}$) were calculated using the curve extrapolation to $(1/C^2=0)$ tabulated in the following table (1).

$$C = K V_R^{-S} \ldots \ldots \ldots \ldots \ldots (2)$$

Where: $K$: is a constant proportionally which its value about $(S = 1/2)$ at abrupt junction and $(S = 1/3)$ at graded junction. $V_R$: reverse bias voltage.

| Dopant percentage | $V_{bi}$(volt) |
|-------------------|----------------|
| CdSe Pure         | 0.1            |
| CdSe:1%Ga         | 0.25           |
| CdSe:3%Ga         | 0.36           |
| CdSe:5%Ga         | 0.6            |

**The Efficiency of Solar Cells (p-n) Junction Measurements:** These results can be tabulated in table (2) which represents the effects of dopant concentrations on the parameters of the solar cell device. The efficiency ($\beta$) and the fill factor (FF) of the CdSe and CdSe:Ga / Si solar cells has been measured for pure and Ga doping by measuring the current density of both short circuit and open circuit voice. The effect of the conversion under illumination effects is also directly proportional to the Ga content in addition to other parameters that have a similar computation.

$$V_{oc} = \frac{kT}{q} \ln \left( \frac{J_m}{J_S} + 1 \right) \ldots \ldots (3)$$

$$FF = \frac{(I_{sc} \times V_{mp})}{(I_{oc} \times V_{oc})} \ldots \ldots (4)$$

$$\eta = \frac{P_m}{P_{in}} = \frac{V_{oc} \times J_{oc}}{P_{in}} \frac{FF}{P_{in}} \ldots \ldots (5)$$
Fig. 3: Current–Voltage characteristics of the CdSe/Si and CdSe:Ga/Si Solar cells illumination conditions.

Table (2): Shows effect of Gallium concentration on (CdSe/Si) solar cells efficiency

| Thin film samples | $V_{OC}$ (mV) | $I_{sc}$ (µA) | F.F % | Efficiency % |
|-------------------|---------------|---------------|-------|--------------|
| CdSe pure         | 76.8          | 57.2          | 29.36 | 2.61         |
| CdSe:1%Ga        | 78.96         | 74.52         | 31.4  | 3.78         |
| CdSe:3%Ga        | 80.5          | 73.2          | 33.51 | 4            |
| CdSe:5%Ga        | 87.1          | 77            | 38.64 | 5.25         |

4. CONCLUSIONS: The I-V characteristic of Ga-doped CdSe solar cell thin film under the illumination conditions gives conversion efficiency of 5.25% at doping ratio 5%. This result of conversion is directly proportional to the Ga concentrations.
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