Photovoltaic Properties of CdS/Si Heterojunction Prepared by DC Plasma Sputtering Technique

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ABSTRACT
CdS/Si heterojunction has been fabricated by dc plasma sputtering technique. Polycrystalline CdS films have been prepared by dc plasma sputtering technique on Si substrate. The current – voltage under illumination showed that the photocurrent increases with increasing incident illumination intensity for CdS/Si heterojunction. The CdS thin films have been sputtered under vacuum of (9×10^{-2} ,8×10^{-2}, 6×10^{-2},5×10^{-2}) mbar, the heterojunction has better photovoltaic properties. The open circuit voltage (V_{oc}) and the short circuit current (I_{sc}) were found to vary with working discharge pressure , and the efficiency is 6.72% at 50.3 mW/cm^2.
Keywords: Solar cell, cadmium sulphide, Plasma, DC sputtering

INTRODUCTION
Cadmium sulphide has a yellow orange color, and two crystal structures, cubic and hexagonal[1], CdS is member of II-VI group of semiconductors, it has a direct energy gap of about 2.4eV[2] , Pure CdS is normally an n-type semiconductor[3], this type of conductivity is essentially due to the non-stoichiometry arisen from the excess Cd in the CdS lattice[4], this material are used as low cost photovoltaic devices and usually used as a very suitable window layers which are prepared as thin as possible to avoid optical transition losses [5,6]**.** This paper describes electrical, characterization and properties of CdS thin films and CdS/Si hetrojunction which are very important in many scientific and industrial applications in the field of optoelectronic device, particularly solar cells [7].

Experimental Details
The target was prepared from cadmium sulfide (CdS) powder (99.99% purity) as a circular shape with (5.1 cm) diameter, (3.7 mm) thickness fabricated by cold fabrication method with (7 Ton) pressured to be used and housed in a vacuum deposition champer for the preparation of thin film. The thin film deposited carried out under different working pressure of order of (9×10^{-2}, $^{8}\times10^{-2}$, 6×10^{-2}, 5×10^{-2}) mbar. The silicon wafer was immersed in very dilute (1:10) ml of ultrahigh-purity HF solution and then washed with deionised water to remove any oil or dust on the substrate surface, and then the slides will be ready to be used.

The conductivity type of the CdS films, mobility μ_n and resistivity σ are calculated using equ. (1) [3] , equ. (2) [3] , and $\sigma(\Omega.cm)^{-1}$ deduced using Hall effect measurement system ECOPIA (HIMS 3000).

$$R_H=1/nq \quad ...(1)$$

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$\mu_n = \sigma/nq = \sigma/R_H$ ...(2)

The (I-V) and (C-V) measurements of solar cell was done under light illumination supplied by a halogen lamp type (PHYLIPS) at power 50.3mW/cm^2 and the voltage applied to the samples in rang of (-3 to 3) V by dc power supply.

The current passing through the cells was measured using digital electrometers, (1A impedance) Analyser 4294A Agilent device was used for measure the parameters of solar cell when Pin=, I–V characteristics F.F and η were calculated by using the equations (3), (4) and (5):[3]

$F.F = (V_{max}\, I_{max})/(V_{oc}, I_{sc})$ ... (3)

$\eta = (V_{ma}\, I_{max})/P_{in}$. ...(4)

$P_m = (V_{oc}, I_{sc})\, F.F$ ...(5)

Results and Discussion

Hall effect phenomena is used to determine the type of the majority charge carriers, concentration (n_H) and Hall mobility (μ_H) for CdS thin films deposited at room temperature with different working pressure, Hall measurement confirms that CdS is n- type, is known as a natural, the coefficient of Hall (R_H) was calculated and listed in tables below.

Table (1): Hall effect measurement at different working pressure

P(mbar)	$\sigma(\Omega.cm)^{-1}$	$R_H(cm^2/C)$	$n_H(cm^{-3})$	$\mu_H(cm^2/V.Sec)$
9×10^{-2}	1×10^{-2}	-9.1×10^{3}	6.86×10^{14}	0.1×10^{-5}
8×10^{-2}	12×10^{-2}	-2.8×10^{3}	2.23×10^{15}	4.2×10^{-5}
6×10^{-2}	1×10^{-2}	-7.4×10^{2}	8.44×10^{13}	0.13×10^{-4}
5×10^{-2}	22×10^{-2}	-1.9×10^{2}	3.2×10^{15}	11.5×10^{-4}

From Table (1), it is clear that decreasing carrier concentration as increases working discharge pressure in this work, on other hand, the increases of mobility results from the inverse relation between μ_H and n_H.

The inverse square of the capacitance is plotted against applied reverse bias voltage for n-CdS/p-Si heterojunctions prepared at room temperatures at fixed frequency of 5 kHz with various working pressure, as shown in Figure (1)

The interception of the straight line with the voltage axis at ($1/C^2 = 0$), represents the built - in potential [8]. It is clear from figure (2) that the built–in voltage decreases with increasing working pressure as a result of increases of the capacitance value and decreases of the depletion width. Another observation is the direct relationship between V_{bi} and the width of the depletion region w. i.e. both V_{bi} and w decreases with increasing the pressure parameter as a result of reduction of optical band gap value with the increasing of working pressure.

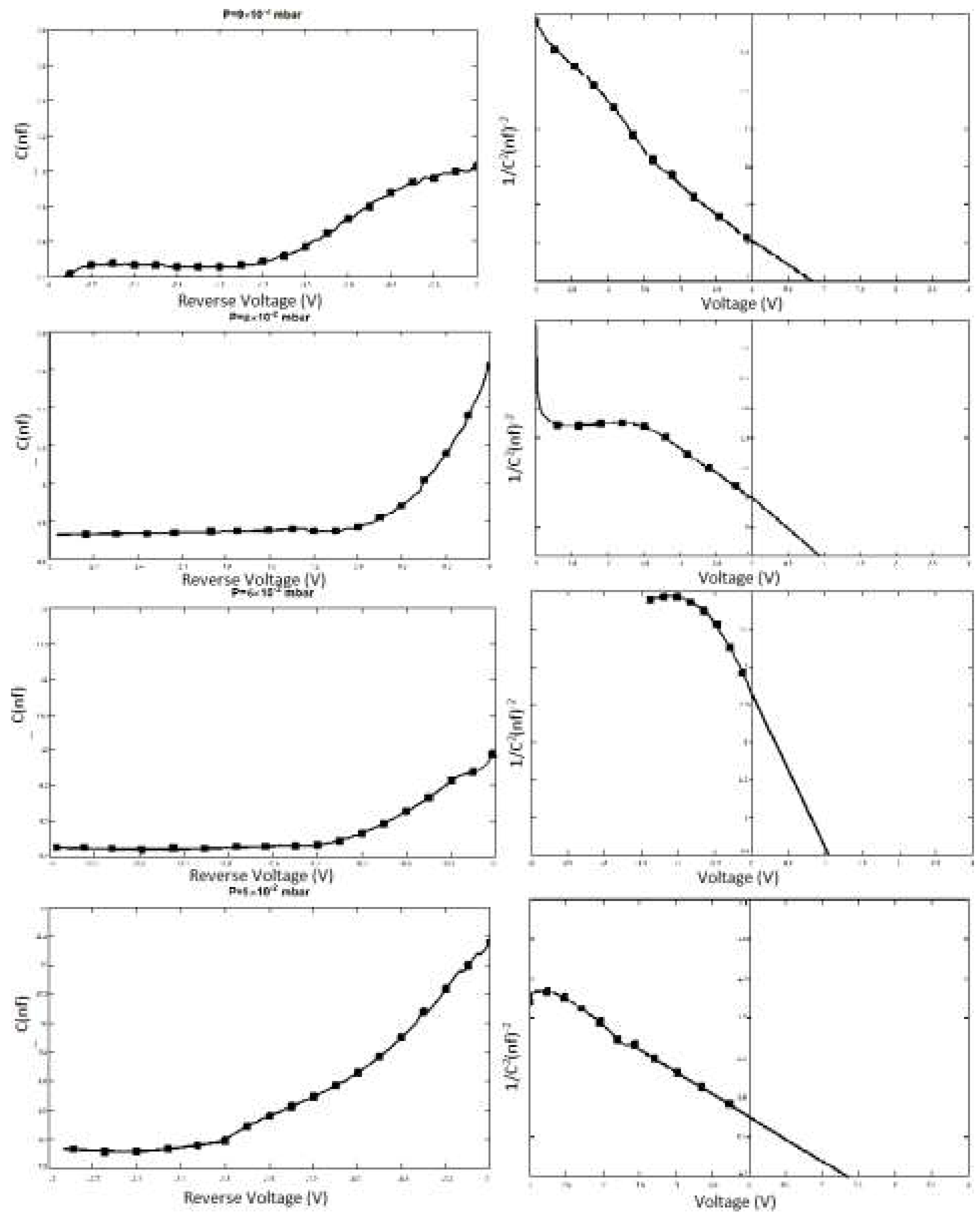

Figure (1): (C-V) characteristics for CdS/Si thin film at different working pressure

The current value at a given voltage for this device under illumination is higher than that in the dark. This indicates that the absorption of light by the active layer p-CdS/n-Si generates carriers contributing photocurrent due to the production of excitons and their subsequent dissociation into the free charge carriers at the barrier interface. It is observed that the photocurrent in the device in reverse direction is strongly enhanced by illumination, under the influence of electric field at the junction, the free electrons and holes were accelerated towards the electrodes across the potential barrier at the interface.

I–V characteristics (V_{oc}, I_{sc}, V_{max}, I_{max}, F.F and η) were calculated and listed in Table (2).

Table (2) Solar cell parameters at different working pressure

P (mbar)	I_{SC} (mA)	V_{OC} (V)	I_{max} (mA)	V_{max} (V)	FF	η%	P_{max}
9×10^{-2}	0.28	2.40	0.21	1.70	0.53	6.72	0.35
8×10^{-2}	0.25	2.42	0.16	1.75	0.64	7.30	0.38
6×10^{-2}	0.19	2.20	0.15	1.40	0.50	3.94	0.20
5×10^{-2}	0	0	0	0	0	0	0

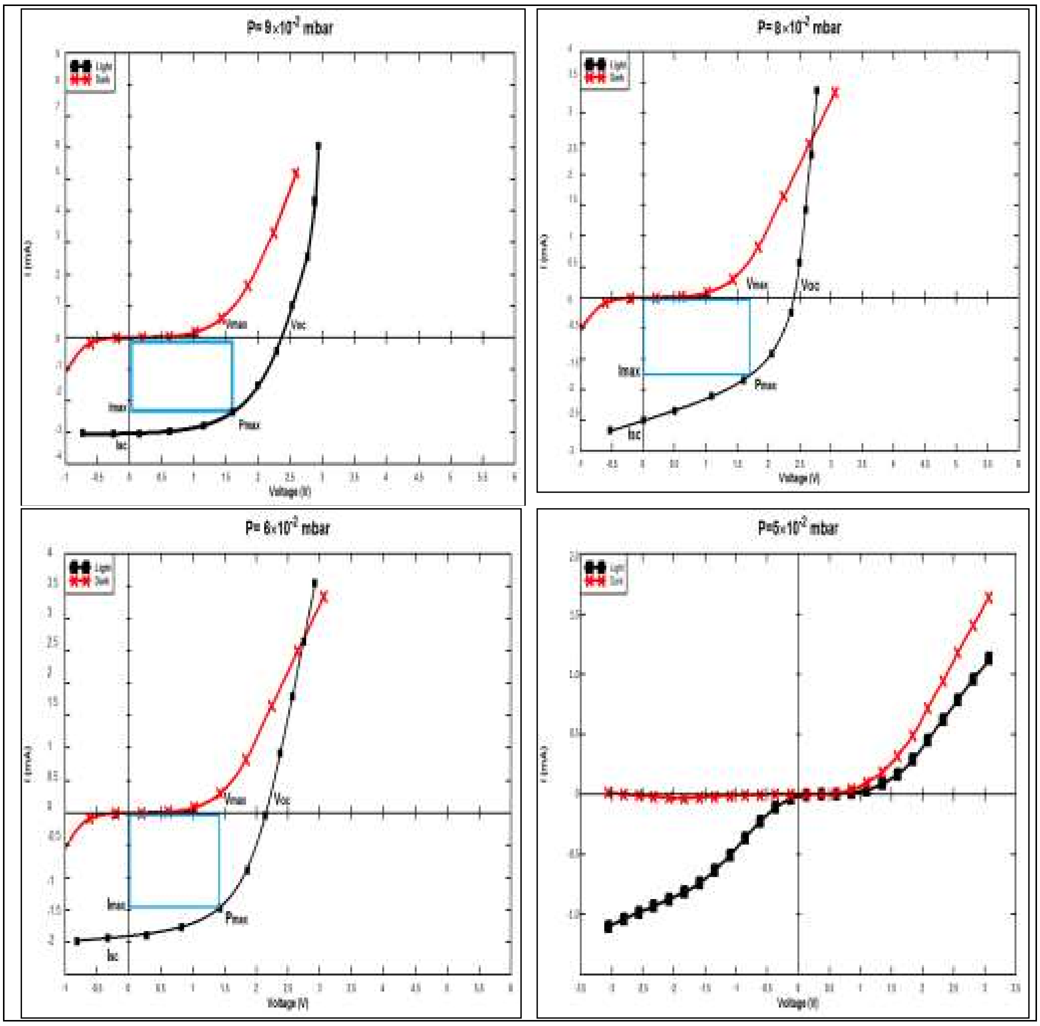

Figure (2): I-V characteristics for CdS/Si thin film heterojunctions under dark and illumination at different working pressures

The spectral responsivity is very important because it specifies the performance of solar cell, R as function of wavelength for spectral range (400-1100) nm of the CdS/Si solar cell is at different working discharge pressures as shown in figure (3).

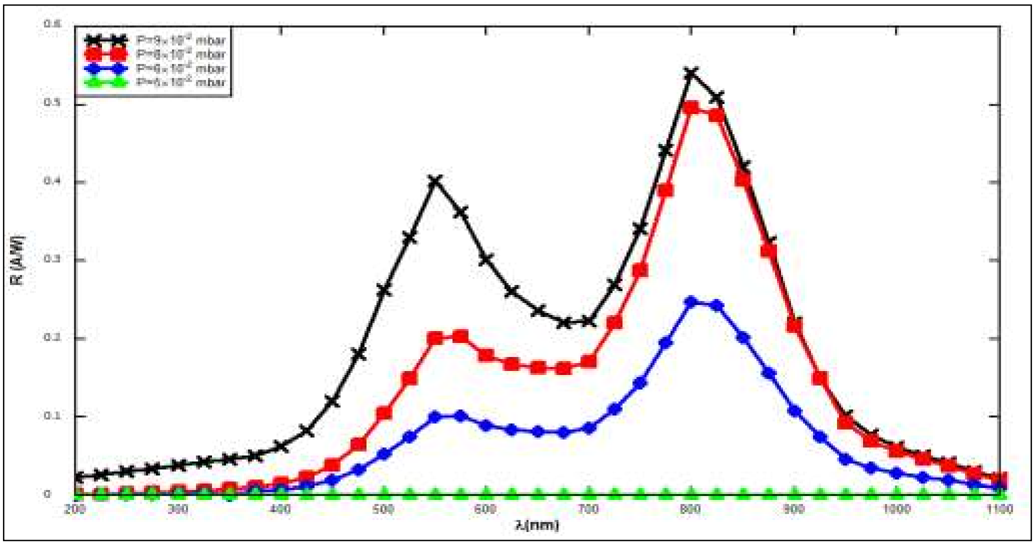

Figure (3): Spectral response of CdS/Si as a function of wavelength at different working pressure

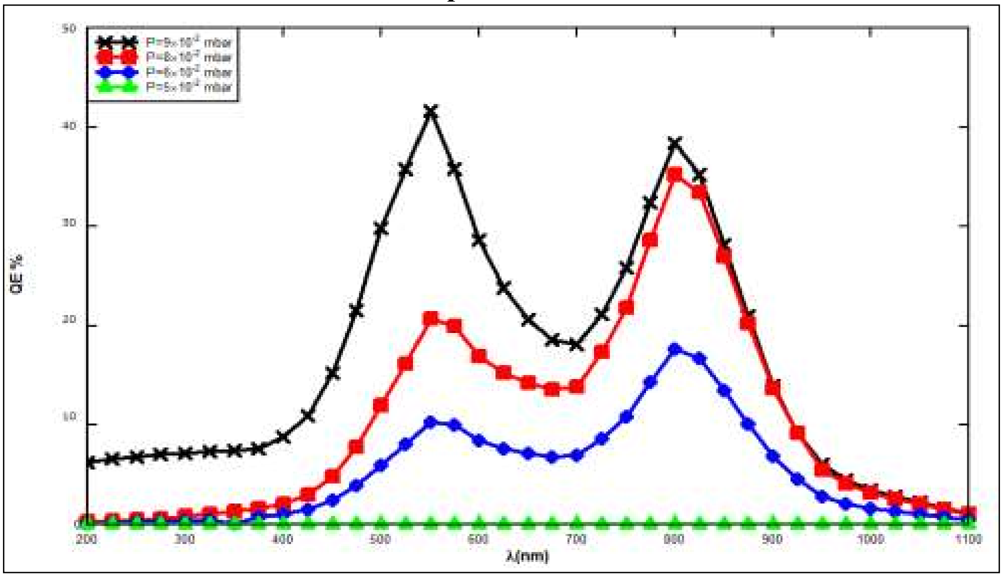

Figure (4): Quantum efficiency of CdS/Si as a function of wavelength at different working pressure

From figure (3), it can observe two peaks first peak at region 550nm ,this peak due to the absorb of light in CdS through band to band absorption, while second region at 800nm, which was due to the Si band gap. From figure (4) we can see the quantum efficiency increase as working pressures increasing because it is related with spectral response.

CONCLUSION

CdS thin films prepared by DC plasma sputtering technique have been examined. The C-V measurements showed that the junction was of abrupt type and the depletion width and built–in potential decreases with increasing of the working discharge pressures. I-V characteristics under illumination showed that the films prepared from n-CdS on the basis of p-Si have good efficiency so can use it as a solar cell.

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