Quantum Efficiency of CdS/CdTe solar cell

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Abstract:

In this theoretical study Quantum efficiency (QE) was calculated numerically as a function of diffusion length (L_p) ,wavelength (λ) and absorption depth (1/α) with different values of each of depletion width (w) , absorption coefficient (α). QE is a powerful tool to characterize (CdS/CdTe) solar cell.

In this study different value of these parameters were assumed to obtain a good QE of (CdS/CdTe) solar cell, also this study shows that the value of QE is (0.96) when ($\alpha=10^4$ cm^{-1}).

Introduction:

The polycrystalline CdS/CdTe cell is more efficient than the single crystal version[1]. The interdiffusion of the hexagonal CdS and cubic CdTe layer is believed to be responsible for overcoming the lattice mismatch[1]. The performance stability of CdS/CdTe solar cells is strongly determined by diffusion of impurities from the back contact into the absorber layer and hetero-junction[2].CdS/CdTe solar cells prepared by high-temperature processes such as vapor transport deposition[3] or closed-space sublimation[4].

QE is a measure of efficiency as a function of wavelength. In other words, how much ,and which parts of the solar spectrum are used by the solar cell. The output of a solar cell is compared to a reference cell with known QE. QE in this way can be determined absolutely assuming the reference cell has not degraded. Measuring the QE of a cell will provide information when cell performances is weak[5].

The QE of a solar cell gives valuable information about the spectral composition of the cells current ,which is determined by carrier generation and collection profiles. The QE is defined at short circuit condition with bias illumination to keep the cell at a reasonable injection level [3].

Quantum efficiency:

The QE is an important parameter for their applications of solar cell and photodetector.The determination of the minority carriers to be obtained proposed the following expression for the QE[6] .

$$QE = (1-R)\left[1 - \frac{e^{-\alpha w}}{(1+\alpha L_p)}\right] \qquad \text{......... (1)}$$

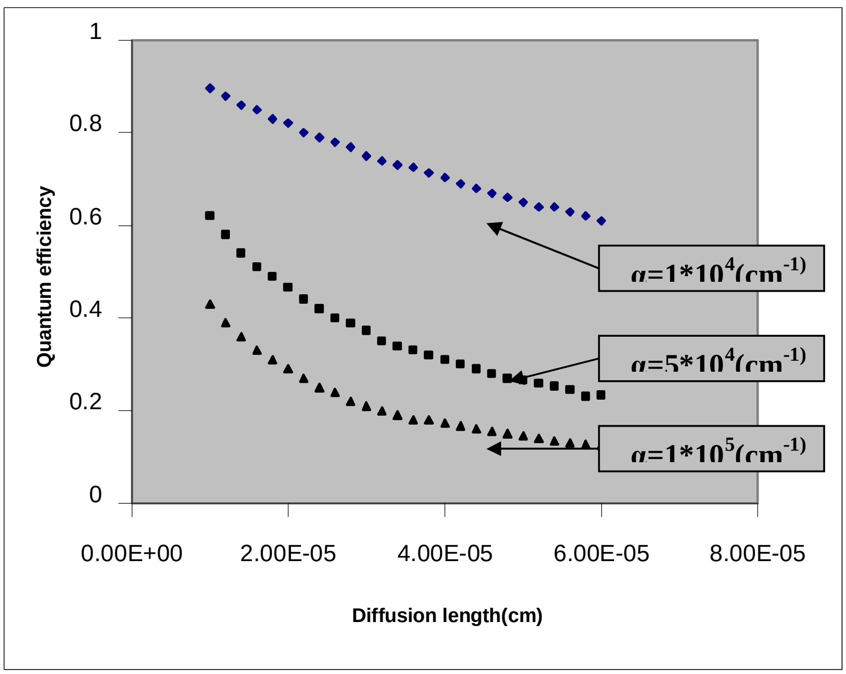
Where(R) and(α)are the reflection and absorption coefficients respectively; (w) is intrinsic depletion layer width; and (L_p)is the diffusion length of the minority carriers. It is also shown that the QE of the electrolyte-semiconductor structure, used for solar energy conversion. It is evident from eq.(1) that increasing the depletion width (w) will increase the diffusion length (L_p) leading to a more efficient device. When (R) is assumed to be equal to zero, Then the equation (1) become :

$$QE = \left[1 - \frac{e^{-\alpha w}}{(1+\alpha L_p)}\right] \qquad \text{......... (2)}$$

From equation (2) the QE is calculated with respect to the diffusion length, wavelength, absorption coefficients, and the absorption depth. These considerations were taken from experimental results done by(Scott[1] ,Gessert[7] Romeo[8] Leonid[9], Ninomiya[10] and Rakhashani[11]) for absorption coefficient, depletion layer and minority diffusion length to obtain the better value of QE . In addition other values of these parameters were assumed under ideal condition.

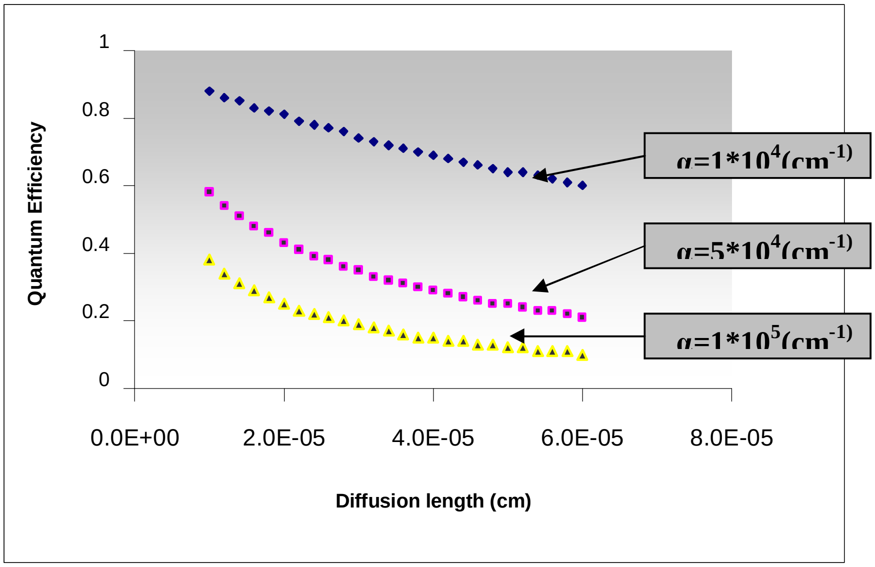
Results and discussion:

The QE of CdS/CdTe solar cell was calculated numerically by using equ.(1) as a function to diffusion length (L_p), absorption coefficient(α) , absorption depth ($1/\alpha$) and wavelength (λ) for many values of depletion width from experimental results[4]. Figure (1) shows QE of the three different absorption coefficient ($\alpha=1*10^4 cm^{-1}$, $\alpha=5*10^4\ cm^{-1}$ and $\alpha=1*10^5\ cm^{-1}$) for a constant value of depletion width ($w=1.39\mu m$)[4]. In this figure the QE decreases when diffusion length is increased and the highest value of QE was at ($\alpha=1*10^4\ cm^{-1}$) , (when diffusion length (L_p) is very small).If the absorption coefficient of the CdS/CdTe solar cell is sufficiently large ,then photogeneration of carrier will primarily occur in the depletion region where the large electric fields enhance carrier transport. Additionally, the low carrier densities in the depletion region tend to minimize recombination of photogenerated carriers. QE therefore tends to decrease at the shorter wavelength where the absorption coefficient is larger.

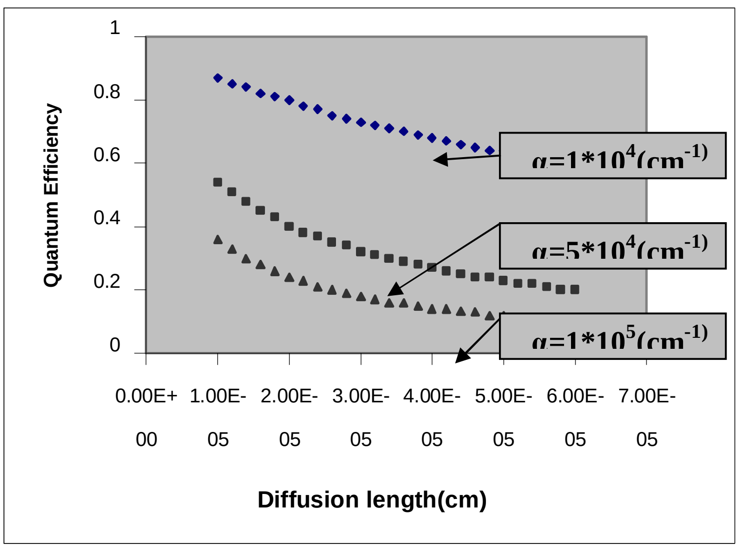


Fig(1) QEvs.diffusion length. when depletion width equal to ($w=1.39\mu m$) and absorption coefficient equal to ($\alpha=1*10^4 cm^{-1}$, $\alpha= 5*10^4\ cm^{-1}$, $\alpha=1*10^5\ cm^{-1}$).

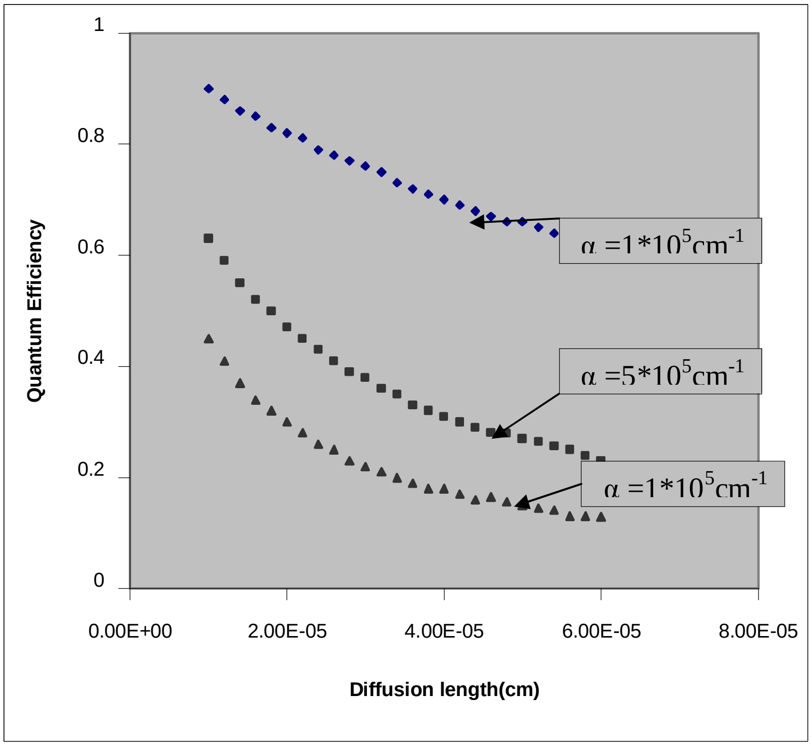
Similar results were obtained when depletion width ($w=2.67\mu m$, $w=4\mu m$ and $w=1\mu m$) as shown in figures (2,3,4) respectively. These results agree with the experimental results[12,13,14,15].



Fig(2) QEvs.diffusion length. when depletion width equal to (w=2.67μm) and absorption coefficient equal to(α =1*10^{4}cm^{-1}, α= 5*10^4 cm$^{-1,}$ α=1*10^5 cm^{-1}).

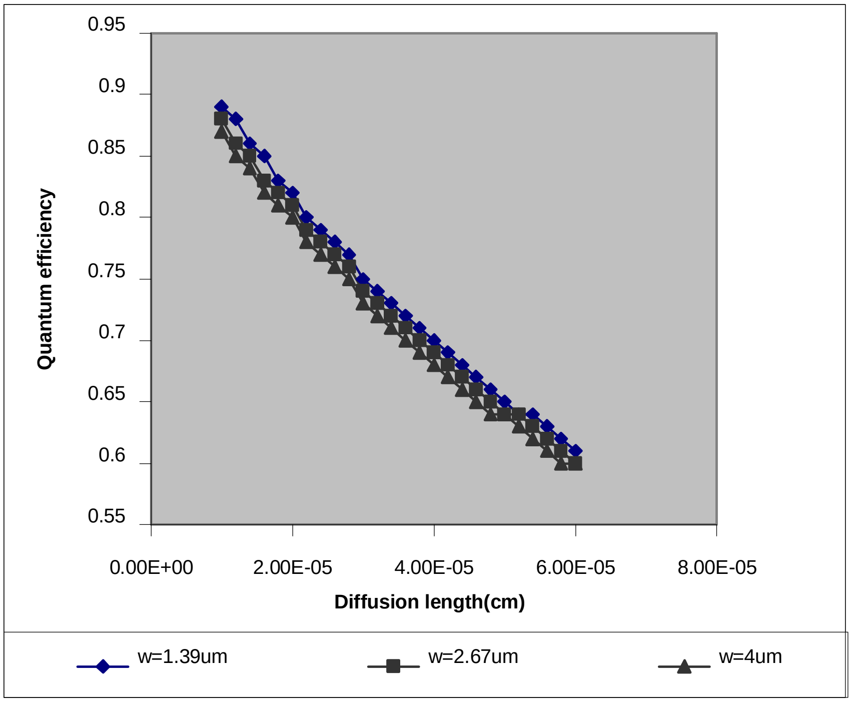


Fig(3)QEvs.diffusion length. when depletion width equal to (w=4μm) and absorption coefficient equal to (α =1*10^{4}cm^{-1}, α = 5*10^4 cm^{-1}, α=1*10^5 cm^{-1}).



Fig(4)QEvs.diffusion length. when depletion width equal to (w =1µm) and absorption coefficient equal to(α =1*10^{4}cm^{-1}, α = 5*10^4 cm^{-1}, α =1*10^5 cm^{-1}).

The relation between QE and diffusion length of three different value of depletion width (w=1.39 µm, w=2.67 µm and w=4 µm) for constant value of absorption coefficient (α=1*10^4 cm^{-1})are illustrated in figure (5), In which the QE is highest when diffusion length is very small and QE decreases when diffusion length is increased. The differences between the three curves were very small for different values of depletion width. In this study it was assumed that the concentration of photogenerated minority carriers in the space charge is negligible, because of this supposition an invariable quantum efficiency may be expected when the light is absorbed and when the majority carriers are generated near the metal-semiconductor boundary. The minority carrier may be transformed directly to the metal and they will not take part in photocurrent in the external circuit and this will lead to a decrease in the QE of CdS/CdTe solar cell at shorter wavelengths[6].



Fig(5)QEvs.diffusion length when absorption coefficient equal to (α =1*10^4 cm^{-1}) and depletion width equal to (w = 1.39µm , w = 2.67µm and w = 4µm).

Figure (6) shows QE as a function of wavelength (λ) for three different values of depletion width (w=1µm, w =1.39µm and w=2.67µm) and diffusion length (L_p=1*10^{-5} cm), It is obvious that the QE decreases when the wavelength was increased and the highest value of QE equal to (0.88)when (λ=400nm); The QE decreases when the amount of the absorption in Cds/CdTe solar cell .With this assumption we can estimate the thickness of this S-rich alloy to be no more than (0.05 µm). Essentially, the only dependence on CdTe thickness down to (0.75 µm) evident from the QE is a gradual decreases in collection across the spectrum(400-800 nm)[3] .This result agrees with another experimental results[16-20]. It Is evident from eq.(1) the decrease in QE lead to increase the absorption coefficient.

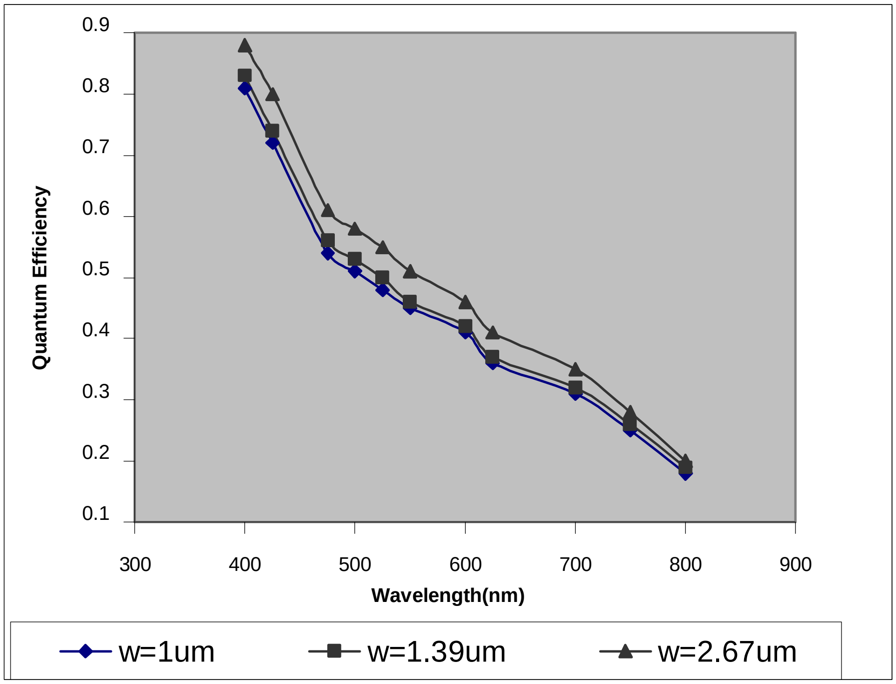


Fig (6) QEvs.wavelength (λ) when diffusion length equal to ($L_p=1*10^{-5}$ cm) and depletion width equal to (w =2.67μm, w =1.39μm and w =1μm).

The QE values as a function of the absorption depth (1/α) with constant value of diffusion length ($L_p=1*10^{-4}$ cm , $L_p=5*10^{-4}$ cm and $L_p=1*10^{-5}$ cm) is illustrated in figure (7). The highest value of QE was (0.96) when (λ=400nm), This result agrees with the results at reference(21).QE measurement gives information about the spectral composition of the current , which can be gained at each working point of the cell .The QE of typical CdS/CdTe solar cell shows three regions of interest. One of them[18,22] is (400-800 nm) which its region dominated by the generation and recombination in the CdS/CdTe solar cell absorber and collection at the pn-junction ,as well as by the resistive of the cell.

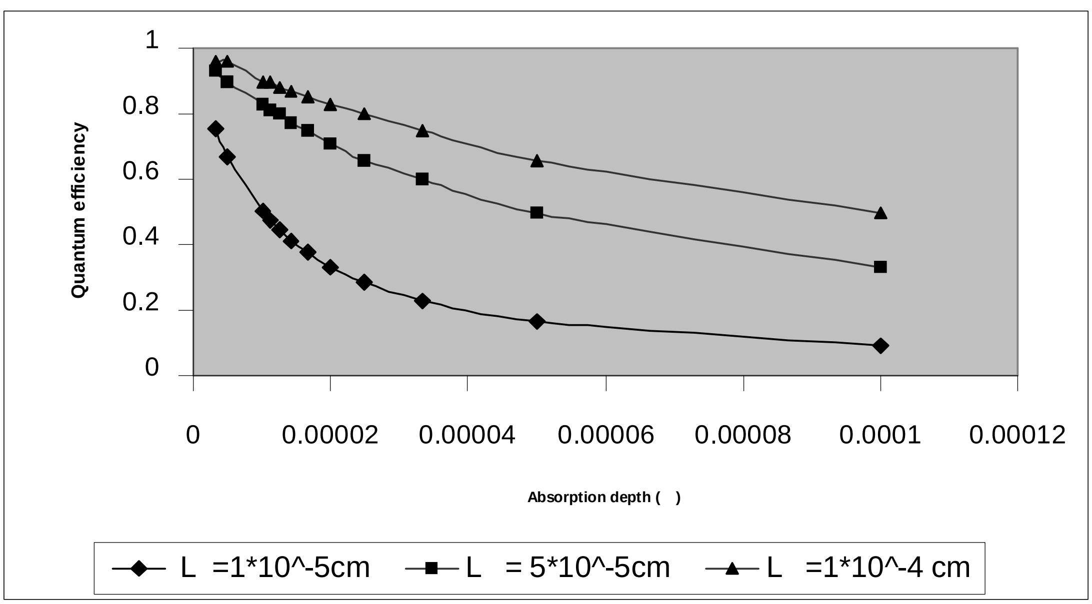


Fig (7) QEvs.Absorption depth (1/α) when diffusion length equal to (L_p = $1*10^{-4}$ cm, L_p = $5*10^{-4}$ cm and L_p =$1*10^{-5}$ cm)

Figure (8) shows QE as a function of absorption Coefficient (α),the highest value of QE equal to (0.96) when (λ = 400 nm). It is clear that the curve in figure (8) [QEvs.(α)] is the inverse of the curve in figure (7) [QEvs.(1/α)]. This result agrees with the experimental results at reference(21).

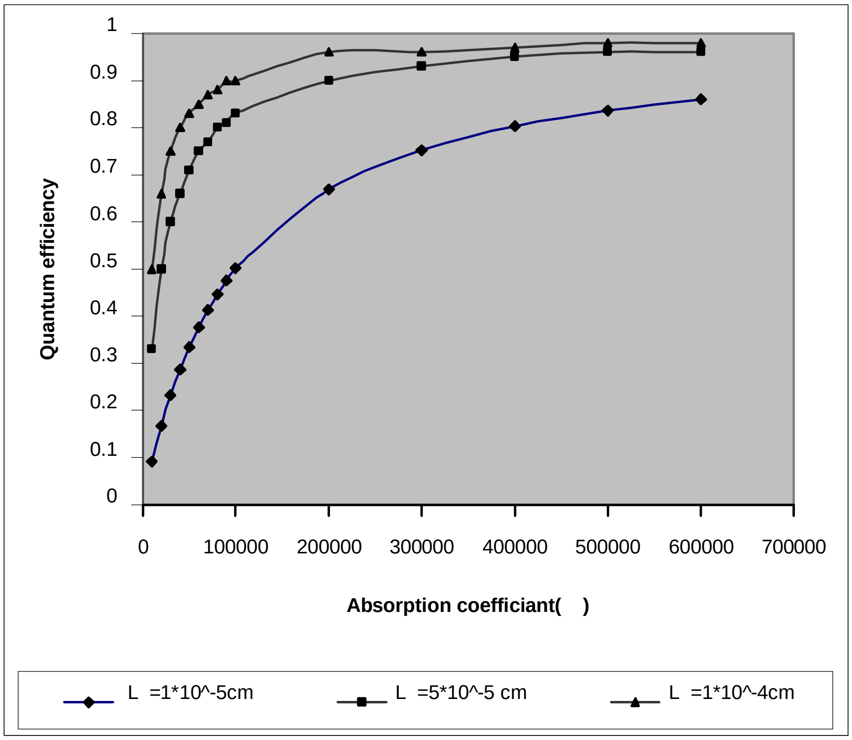


Fig (8) QEvs.Absorption coefficient (α) when diffusion length equal to (L_p =1*10^{-4} cm, L_p = 5*10^{-4} cm and L_p =1*10^{-5} cm)

Conclusion:

The highest value of Quantum efficiency of CdS/CdTe solar cell (0.96) was obtained when (L_p = 1*10^{-4} cm) , (α =1*10^{4}cm^{-1}) and (w =1μm), this is an important when one want to fabricate a Solar cell to get a good value of QE and a good performance of CdS/CdTe solar cell .

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خلاصة البحث:

في هذه الدراسة النظرية تم حساب الكفاءة الكمية عددياً للخلايا الشمسية (نوع CdS/CdTe)كدالة لطول الانتشار (L_p) ، الطول الموجي(λ) و عمق معامل الامتصاص($1/\alpha$) لقيم مختلفة لعرض منطقة النضوب ومعامل الامتصاص. كما افترضت عدة قيم للمتغيرات أعلاه للحصول على قيمة عالية للكفاءة الكمية والتي كانت تساوي (0.96) عندما يكون معامل الامتصاص مساوياً إلى ($\alpha = 1*10^4 cm^{-1}$) وطول الانتشار ($L_p = 1*10^{-4}$ cm)وعرض منطقة النضوب($w=1\mu m$) .