Int. J. Nanoelectronics and Materials **5** (2012) 87-94

The effect of diffusion temperatures on the detection properties of CdS/p-Si and CdS:In/p-Si Heterojunctions

H. F. Ali [1], E. M. N. Al-Fawade[1], S. K. J. Al- Ani [3,]

[1]*Physics Department, College of Science for Women, University of Baghdad, Baghdad, Iraq*
[2]*Physics Department, College of Science, University of Baghdad, Baghdad, Iraq*
[3]*Physics Department, College of Science- Al-Mustanseriya, University-Baghdad-Iraq*

Received 18 July 2010; Revised 23 Feb. 2011; Accepted 23 March 2011

Abstract

The detection properties of of CdS/p-Si and CdS:In/p-Si heterojunction (HJs) prepared by thermal evaporation method have been studied . These films were doped with in 2% by thermal diffusion method at diffusion temperatures (T_d=200,250,300,350^{o}C). Pure n-CdS/p-Si and doped n-CdS:In/p-Si heterojunction types at different diffusion temperatures have been prepared by deposition pure and doped CdS thin films on p-type single crystal silicon. The detectivity of these HJs is broad and lies in the range (500-1100) nm with two peaks for pure n-CdS/p-Si at 550nm and 800nm have been observed. For doped n-CdS:In/p-Si HJ the peaks were located at 650nm and 800nm and for two types of HJs the first peak was for CdS and CdS:In and the second peak was for silicon. The value of noise equivalent power (NEP) decreases with increasing diffusion temperatures (2.76, 2.42, 2.17, 1.38) x10^{-11} W for (Pure, T_d=200, 250,300 ^{o}C) respectively and then increased to 2.13 x10^{-11}W at 350 ^{o}C. The detectivity also increases with increasing T_d (0.108, 0.165, 0.166, 0.217, 0.155) x10^{11}cm.Hz$^{1/2}$.W^{-1} for (Pure at 550nm, doped at 650nm for T_d=200, 250,300 ^{o}C) then decreases at 350 ^{o}C.

Keywords: Detectivity; CdS/p-Si; Heterojunction detectors; Diffusion temperatures.
PACS: 85.60.GZ; 85.60.Bt; 81.05.Dz; 81.15-z.

1. Introduction

CdS is technologically a useful material, as many devices based on CdS, including sensors that have come up in the recent years. The thin film cadmium sulphide solar cell has for several years been considered to be a promising alternative to the more widely used silicon devices [1]. CdS thin films are regarded as one of the most promising materials for heterojunction thin film solar cells. Wide band gap CdS (E_g = 2.4 eV) has been used as the window material together with several semiconductors such as Si, CdTe, Cu_2S, InP and $CuInSe_2$ with 14 – 16% efficiency. For the development of such optoelectronic devices, CdS thin films require comprehensive optical characterization. Many techniques have been reported for the deposition of CdS thin films. These include evaporation, sputtering, chemical bath deposition, spray pyrolysis, metal organic chemical vapor deposition (MOCVD), molecular beam epitaxy (MBE), electro deposition, photochemical deposition etc [2]. In spite of the huge lattice mismatch of about 7%, CdS/Si heterojunction was considered one of the promising heterojunction devices [3].

Noise Equivalent Power (NEP) is defined as incident radiation power required to produce signal equal to the r.m.s noise voltage (S/N) or can be defined as the generated current noise (I_n) divided by the spectral responsivity

(R_λ) of the detector as in the relation below:

$$NEP = I_n / R_\lambda \tag{1}$$

$$I_n = (2qI_d\, \Delta F)^{1/2} \tag{2}$$

Where q is the charge of the electron, I_d is dark current and ($\grave{}\Delta F$) an electrical bandwidth of 1 Hz.
Detectivity (D) is originally defined as reciprocal of NEP [4]:

$$D = 1/NEP = R_\lambda / I_n \tag{3}$$

And specific detectivity (D^*) also known as normalized detectivity, is a reciprocal of the NEP, normalized to a detector area ($a\grave{}$) of 1 cm^2 and with assuming that the detectivity noise varies with $a\grave{}^{1/2}$and $\Delta F^{1/2}$. The (D^*) is expressed as [5]:

$$D^* = (a\grave{}\ \Delta F)^{1/2}/NEP \tag{4}$$

Or [4]:

$$D^* = R_\lambda\, (a\grave{}\ \Delta F)^{1/2} / I_n \tag{5}$$

The value of D^* is independent on the size of detector and depends on the wavelength of signal radiation and frequency at which it is modulated [4, 5]. In the present paper, pure n-CdS/p-Si and doped n-CdS:In/p-Si heterojunctions are prepared and the effect of diffusion temperatures of indium on the detection properties for these heterojunctions have been studied.

2. Experimental

Pure cadmium sulphide films and doped with in at different diffusion temperatures (T_d=200, 250, 300 and 350 ^oC) have been deposited by vacuum evaporation onto cleaned single crystal p-type silicon wafers of (111) orientation, (1-5) Ω.cm resistivity, 500μ thickness and substrate temperatures (T_s) of 100^{o}C. Prior to film deposition, the wafers were etched by dilute hydrofluoric acid (1:10) HF:H_2O to remove native oxide. Subsequently, the back contacts are accomplished by vacuum evaporating (300nm) of five nines Al. After completing the deposition, the front metal contact is made by evaporating (300nm) of five nines Al through a metal mask. Figure (1) represents the schematic diagram of pure n-CdS/p-Si and doped n-CdS:In/p-Si heterojunction structures .

Specific detectivity was calculated from spectral response measurements (with the aid of a monochromator, 400-1100 nm range type INFRARED SPECTRO RADIOMETER OPTRONIC LABORATORIES INC.U.S.A.MODEL (746) and dark current measurements at zero bias voltage (with the help of an electrometer with 12 digits of ampere accuracy as in Fig. 2.

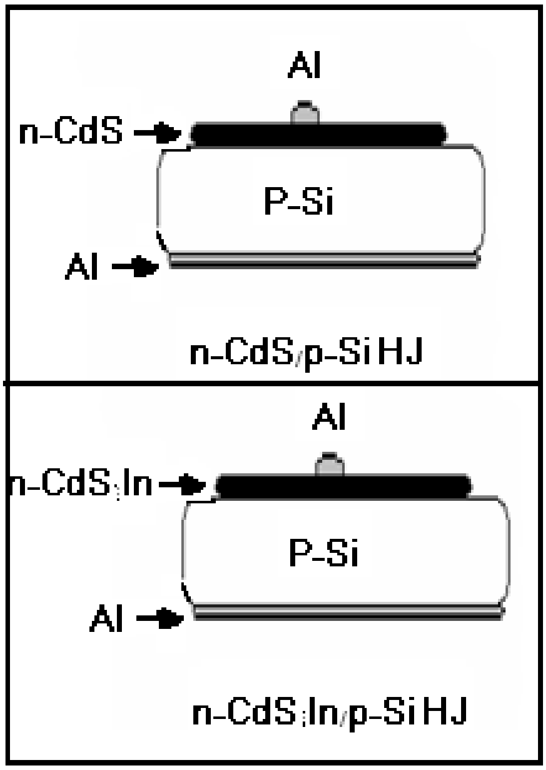


Fig.1: Represent the schematic diagram of pure n-CdS/p-Si and doped n-CdS:In/p-Si Heterojunctions.

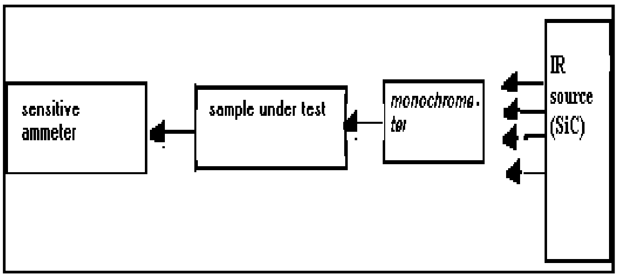
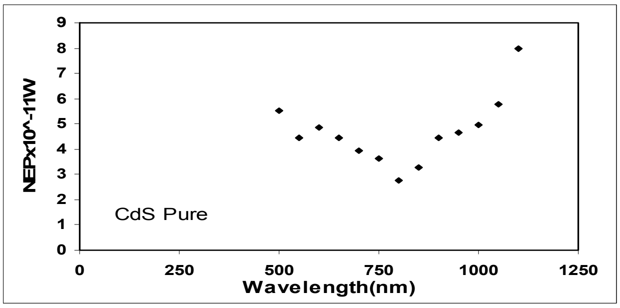


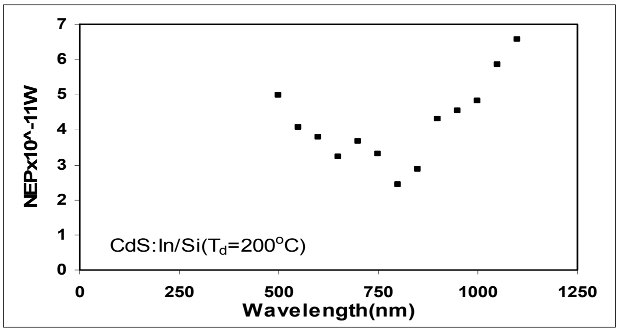
Fig. 2: Photocurrent measurement.

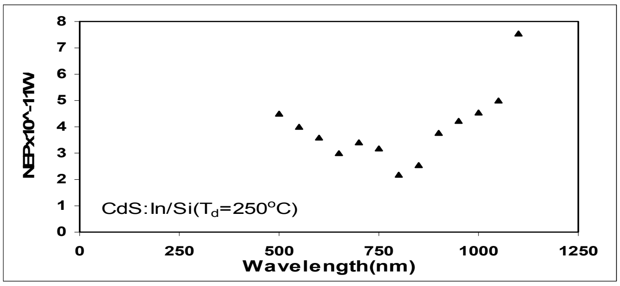
3. Results and Discussion

The noise equivalent power values calculated by equation (1) is shown in Fig.(3) and listed in Table I for pure n-CdS/p-Si and doped n-CdS:In/p-Si heterojunctions at different diffusion temperatures (T_d=200, 250, 300 and 350 °C). It can be seen that the maximum responsivity occurs when NEP has the minimum values. From the calculations of NEP and D^* curves, the detectivity of the HJs is found broad and lies in the range (500-1100) nm with two peaks for pure n-CdS/p-Si at 550nm and 800nm have been observed. For doped n-CdS:In/p-Si heterojunctions the peaks were at 650nm and 800nm and for two types of heterojunction, the first peak was for CdS and CdS:In and the second peak was due to silicon. The value of noise equivalent power (NEP) decreases with increasing diffusion temperatures (2.76, 2.42, 2.17, 1.38) $\times 10^{-11}$W for (Pure, T_d=200, 250,300 °C) respectively and then increased to 2.13 $\times 10^{-11}$W at 350 °C. This is due to the reduction of the defects by increasing the diffusion temperatures .Thus causing recrystallization the lattice by adding both the impurity and the temperature which decreases the noise current. The increase in NEP at 350 °C may be due to the affect of in impurity.

It can also be seen from Figure(3) that for pure CdS film at wavelength less than 550nm , the value of NEP is very high, while in the range 550nm, the value decreases to minimum value, then NEP is increased to maximum value at wavelength higher than 550nm. While for CdS:In at (T_d=200, 250,300 and 350 °C) at wavelength less than 650nm , the value of NEP is very high, while at range 650nm, the value decreases to minimum value, then NEP is increased to maximum value at wavelength higher than 650nm (this means that the maximum responsivity occurs when NEP at the minimum value, then the noise must be made as less as possible in the HJ). The reported values of NEP for CdS are $0.4x10^{-11}$ W and $2.5x10^{-12}$ W prepared by chemical spray pyrolysis[6, 3] .







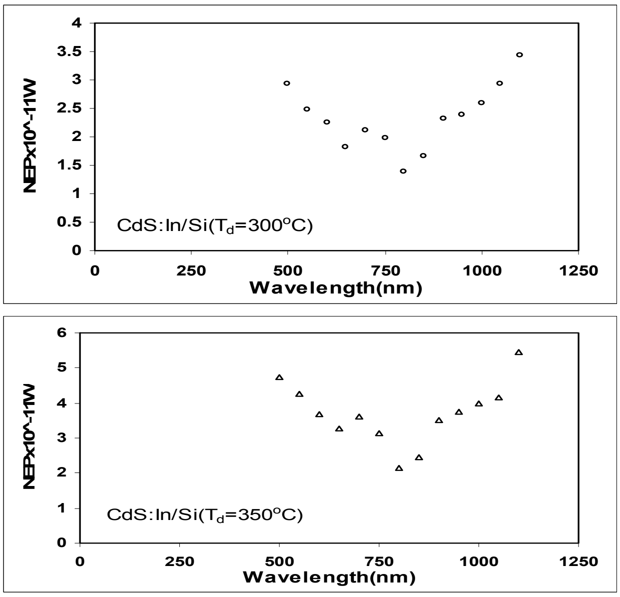


Fig. 3: NEP for pure n-CdS/p-Si and doped n-CdS:In/p-Si heterojunctions at different diffusion temperatures (T_d=200, 250, 300 and 350 °C).

Table 1: The NEP and D* at 550 nm and 650 nm wavelength for pure n-CdS/p-Si and doped n-CdS:In/p-Si HJs respectively.

T_d °C	NEP x10^{-11} W	D^* x10^{11}cm.Hz$^{1/2}$/W
Pure	2.76	0.108
200	2.42	0.165
250	2.17	0.166
300	1.382	0.217
350	2.13	0.155

The specific detectivity D* is one of the main criteria parameters which lead to a suitable application of the detector and it represents the minimum signals which the detectors can detect. It can be seen from Fig.(4) and Table I that the value of detectivity increases with increasing T_d due to :

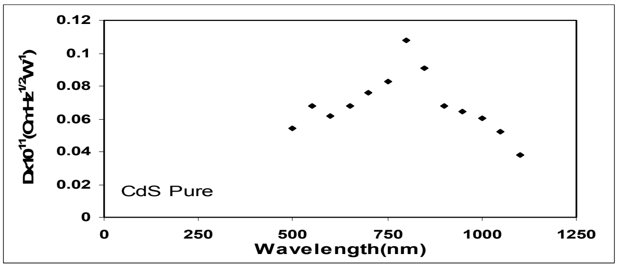
1. Decreases of dark current I_d , this is related to the noise current I_n according to equation (2).
2. Decrease the defect that leads to increase the recrystalline processes in the material which affect the value of D*.

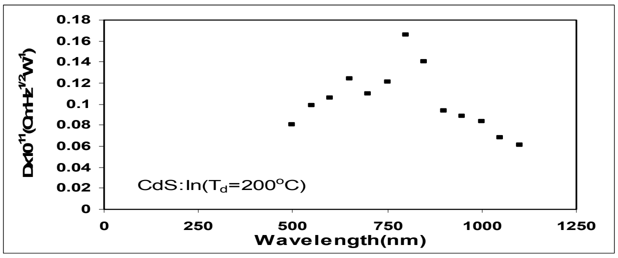
Figure 4 shows the specific detectivity (D*) vs. wavelengths (400 to 1100 nm) for a selected CdS/Si heterojunction photo detector prepared at T_s =100°C. Over this span of wavelengths, there are two distinct peaks, the first one (at 550 nm and 650 nm) is related to the contribution of CdS absorption and CdS:In, while the second (at 800 nm) represents the absorption in the silicon side. The minimum at 550 and 650 nm is attributed to the absorption in the interface in which high density of states exist.

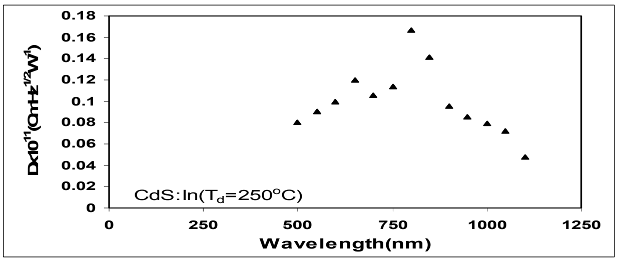
From Table I it can be seen that the maximum value of D* is at 300 °C value because it has the minimum dark current, and this value is in agreement with other researchers [7].Thus, it can be seen that the best diffusion temperatures is at 300 °C . The minimum incident power that falling on a detector and can be measured is the specific detectivity .This is one of the parameters that is frequently used to determine the suitable application of the detector. It may be useful to compare the detector's parameters such as NEP and D*of our HJs with the corresponding values for the tradition $Pb_x S_{1-x}$ photocoductor detectors as shown in Table 2.

Table 2: The NEP & D* parameters of some photodetector systems.

NEP(W)	**D* cm $Hz^{1/2}$ W^{-1}**	**Reference**	**System**
$1.382x10^{-11}$	$0.217x10^{11}$	Present work	n-CdSi: In/p-Si HJs
$0.4x10^{-11}$	$2X10^{11}$	[6]	Chemical sprayed CdS-Si films
$2.5x10^{-12}$	$1.8X10^{12}$	[3]	= =
$3x10^{-9}$		[8]	PbS films
	10^{12} at 77K	[9]	PbS
	$4.5x10^{8}$ at room temperature		
	$1.6x10^{6}$	[10]	Electro-deposited PbS films
$0.54x10^{-12}$	$1.84x10^{12}$	[11]	$Pb_{0.55}$ $S_{0.45}$
$2.2 x10^{-12}$	$0.437x10^{12}$		$Pb_{0.50}$ S_{50} Flash evaporated films
	$4.1x 10^{10}$ at λ= 2.2 µm	[12]	PbS-Si HJ







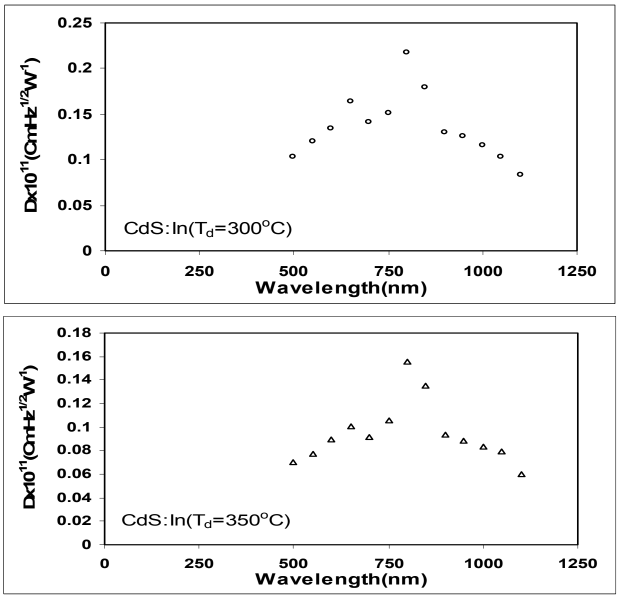


Fig. 4: D* vs wavelength for pure n-CdS/p-Si and doped n-CdS:In/p-Si heterojunctions at different diffusion temperatures (T_d=200, 250, 300 and 350 °C).

4. Conclusions

Pure n-CdS/p-Si and doped n-CdS:In/p-Si HJs at different diffusion temperatures have been prepared successfully by vacuum evaporation method at substrate temperature of 100 °C. The detection properties for these junctions have been studied.

The detectivity of these detectors have shown two peaks for pure n-CdS/p-Si at 550nm and 800nm whereas for doped n-CdS:In/p-Si HJ , the peaks were located at 650nm and 800nm . In the two types of heterojunction the first peak was for CdS & CdS:In and the second peak was for silicon. The value of noise equivalent power (NEP) decreases with increasing diffusion temperatures and then started to increase. Also the detectivity increases with increasing T_d and then tends to decrease. The best diffusion temperature was 300 °C . The detector's parameters obtained in this work are comparable with the Pb_x S_{1-x} photoconductor detectors.

References

[1] P. Raji, C. Sanjeeviraja, K. Ramachandran, Bull. Mater. Sci., **28** (3) (2005) 233
[2] P. P. Sahay, R. K. Nath, S. Tewari, Cryst. Res. Technol., **42**(3) (2007) 275
[3] O. A. Abdulrazaqi, E. T. Saleem, Turk. J. Phys, **30** (35) (2006) 39
[4] P. W. Krus, *Optical and Infrared Detectors,* ed. R. J. Keyes Springer-Verlag Berlin, Heidelberg, **19** (1977)
[5] W. Budde, Academic press, **4** (1983) 215
[6] R. A. Ismail. A. M. Al-Samarai, O. A. Sultan, Al-Rafidain Eng.J. **8**(2) (2000)77
[7] T. S. Moss, *Optoelectronic Properties of Semiconductor,* Academic press, London (1970)

[8] M. Smollet, J. Jenkins, Electronic Engineering, **22** (1956) 373

[9] K. L. Chopra, D. K. Pandya, Thin Solid Film, **50** (1978) 81

[10] H. Salonimi, *Electro deposition of PbS,PbSe and PbTe thin films,* Ph.D thesis, University of Helsinki , Finland (2000)

[11] M. F. A. Alias, E. M. N. Al-Fawade A. A. Alnajjar, A. A. J. Al-Douri, University of Sharjah Journal of Pure and Applied Sciences, **3**,.n.3(2006)1

[12] H. J. Hov and A. G. Milmes, Int. J. Electron, **24** (1968) 201