ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.9, No.11 pp 331-336, 2016

Optoelectronic properties of detector (p-$Cd_{1-x}Zn_xS$ /n-Si) preparing by Spray Pyrolysis Technique

Nahida B. Hassan, Rusul A.Ghazi*

Department of Physics, College of Science, University of Babylon, Iraq

Abstract : A thin films (160±3 nm) of $Cd_{1-x}Zn_xS$ were deposited on the wafer silicon, with high purity (99.999%).This heterojunction (p-$Cd_{1-x}Zn_xS$ /n-Si) prepared by Spray Pyrolysis technique. The spectrum responsivity of this detector was measured, and calculation each of the quantum efficiency, noise equivalent power, detectivity and specific detectivity. From the characteristic above, the heterojunction (p-$Cd_{1-x}Zn_xS$ /n-Si)was determined as a detector of visible at (650 nm) and the near infrared light at (950nm) within spectrum(400-1100 nm).

Introduction

(p-$Cd_{1-x}Zn_xS$ /n-Si) heterojunction can be used for fabrication of a number of types of electronic devices, such as photodetectors, diodes and sensors of temperature and solar cell. It is well known[1,2] that optical and electrical properties of Si heterojunctions are strongly depended on the technological conditions of heterojunction formation. So study of the details of these dependencies is of interest for both semiconductor materials science and instrument device fabrication. This paper deals with investigation of $Cd_{1-x}Zn_xS$ films deposited on Si wafer by Spray Pyrolysis technique.

Theoretical Background

All detectors used in spectrometers function by converting the incident radiation into an electrical signal which can be amplified and recorded by conventional apparatus, the general requirements for the detector are[3]:

1. High sensitivity: The detector should produce a large output signal (generally electrical) for a small radiation input.
2. Low noise: Inevitably, in the absence of radiation a detector will produce some signal (noise). This limits the smallest genuine signal that can be detected.
3. Linearity: The output of the detector should be proportional to the radiation input, so that accurate photometric measurements can be made. The constant of proportionality (gain) should be independent of the wavelength of the radiation[4].

Detectors can be classified into two main groups according to the mechanism of this conversion[3-5]:

1. Thermal detectors: detect the heating of an absorbing receiving element due to the absorbed radiation energy.
2. Photon detectors: Absorption of one quantum of radiation releases a quantity of electrical charge, which can be detected in one of two ways: pulse counting, which records directly the number of events taking place in the detector, or rate measuring, which integrates the charge released during a given time, and thus measures the rate of arrival of photons. Photon detectors function in one of two ways[3]:

a) External photoelectric effect: the energy of a photon is large enough to free a charge carrier (electron) completely from the sensitive receiver surface.
b) Internal photoelectric effect: the energy of the photon is not sufficient for (a) but is large enough to raise a charge carrier (electron or hole) in a semiconductor into the conduction band. Three types of internal photoelectric effect are of practical importance[6,7]:

1. The charge carriers increase the conductivity of the semiconductor photoconductive effect.
2. The carriers are generated at a point in the semiconductor at which a potential barrier exists, and a voltage is produced by charge separation- photovoltaic effect.
3. Charges are separated by diffusion in opposite directions in a magnetic field photoelectromagnetic effect.

Experimental Steps

$Cd_{1-x}Zn_xS$ films were deposited on silicon wafer substrate by spray pyrolysis method . A n-type single – crystal silicon wafers with (111) orientation are used as substrates. They have a resistivity of the order 10 Ω.cm. Prior to the deposition of the $Cd_{1-x}Zn_xS$ films, the silicon wafer was immersed in diluted HF solution and then washed with deionized water to remove the native oxide. The $Cd_{1-x}Zn_xS$ films were grown on Si by using the ($Cd\,CH_3\,COOH_3.2H_2O$) in molarity of 0.1 M as a source of cadmium ions ($ZnC_4H_6O_4.2H_2O$) in molarity of 0.1 M as a source of Zinc ions and 0.1 M thiourea [$SC(NH_2)_2$] as a source of sulphideions. The solution was stirred to ensure homogeneous dissolve about 5 minutes. The thickness of the film was determined with using Lambda (LIMF-10), microbalance. The $Cd_{1-x}Zn_xS$ thickness of the films was found to be approximately 160 ± 3 nm.

Measurements & Calculations

The photocurrent resulted from the heterojunction (p-$Cd_{1-x}Zn_xS$ /n-Si) were measured by using detectors testing system which consist of monochrometer which due at the spectrum 400- 1100 nm consisting of halogen lamp 250W, diffraction gratings with analytical ability 100nm , lenses which due to accumulation of the light approaching from diffraction .

After measuring the photocurrent, the responsivity was calculated by using the equation[4]:

$$R_\lambda = \frac{I_{ph}}{P_{in}} \quad \text{or} \quad R_\lambda = \frac{V}{P_{in}} \quad \cdots\cdots\cdots\cdots (1)$$

hence :R_λ: Responsivity, I_{Ph}: photo current density. P_{in}: incident light intensity (W/cm^2)

It is very important to know the range of spectrum for each detector, optimum region in this range which determined by responsivity of the detector which is distinct and differentiates this detector from the rest[8].

The quantum efficiency (η) was measured by using[9]:

$$\eta = R_\lambda \cdot \left(\frac{h\upsilon}{e}\right) \quad \cdots\cdots\cdots\cdots (2)$$

$$\eta = R_\lambda \cdot \frac{1240}{\lambda} \quad \cdots\cdots\cdots\cdots (3)$$

λ: frequency .

The equivalent noise power (NEP) was calculated, which is defined as the lesser power that could be detected by the detector, was measured by the equation[10]:

$$NEP = \frac{I_n}{R_\lambda} \quad \cdots\cdots\cdots\cdots (4)$$

hence I_n: noise current which measured by[5]

$$I_n = (2\,e\,I_d\,\Delta f)^{\frac{1}{2}} \quad \cdots\cdots\cdots\cdots (5)$$

Where I_d is dark current, Δf is band width.

so the detectivity (D) could be defined as the invert of the (NEP), or it is the ratio of responsivity to noise current (I_n) of detector[4]:

$$D = \frac{1}{NEP} = \frac{R_\lambda}{I_n} \qquad \cdots\cdots\cdots\cdots (6)$$

so another parameter defined as specific detectivity (D*) which determined by the following relation [4] :

$$D^* = D(A\,\Delta f)^{\frac{1}{2}} \qquad \cdots\cdots\cdots\cdots (7)$$

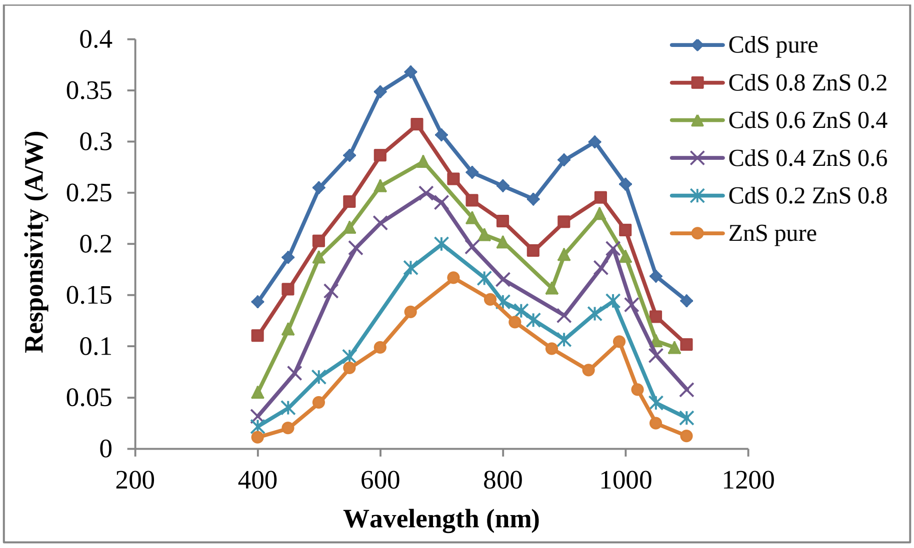
A :is active area of detector. The detectivity was measured by units (W^{-1}); the specific detectivity by (cm.Hz½.W^{-1}). It's important to mention that all measurements conducted without using bias, i.e. the detector itself is photovoltage detector.

Results & Discussion

1.Responsivity

Figure (1) illustrate the characteristics of responsivity of heterojunction (p-$Cd_{1-x}Zn_xS$ /n-Si) as a function of wavelength which is calculated by equation (1), one can notice from this figure that there are two peaks, the first peak located at visible range and second peak located at near IR range. That increase of x concentration in $Cd_{1-x}Zn_xS$/n-Si films causes a decrease in the spectral responsivity value for all wavelength range. This is because of the increasing of the defect concentrations which act as recombination centers concentrated on the two sides of the interface.

In this case the responsivity depending on the absorption coefficient of each of (Si) and $Cd_{1-x}Zn_xS$, which each of them due at specific range, in despite of responsivity could be shown between them revealed the homogeneity of two semiconductors.



Figure(1): The variation of responsivity as a function of wavelength for p-$Cd_{1-x}Zn_xS$/n-Si heterojunctionat different Vol.% of (x).

2.Quantum efficiency

Figure (2) shows the quantum efficiency characteristics as a function of wavelength of heterojunction (p-$Cd_{1-x}Zn_xS$/n-Si). The quantum efficiency was calculated according to equation (3), so it noticed that the quantum efficiency altered with responsivity.

Two peaks observed clearly in the same figure. The different between two peaks efficiency were observed, because that the different basically depending on the quantum efficiency definition, so the incident photons energy within absorption range of (Si) larger than photons energy within absorption range of $Cd_{1-x}Zn_xS$ reviewed the item[1, 4] so the number of the electron – hole pairs which generated for each incident photon of the first range was greater than the second range subsequently the quantum efficiency is higher at the first range peak comparing with the second range peak, because of increasing of the generated pairs number.

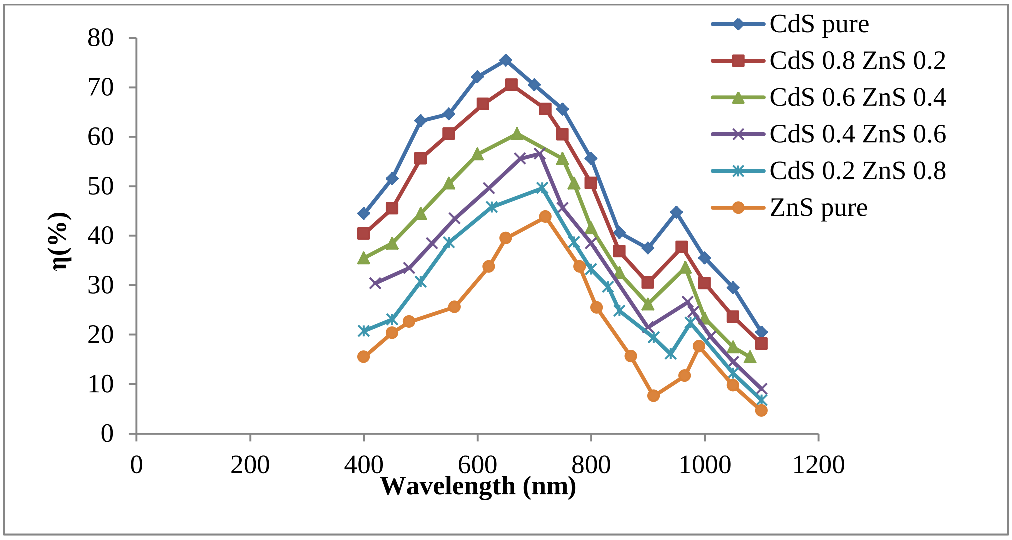
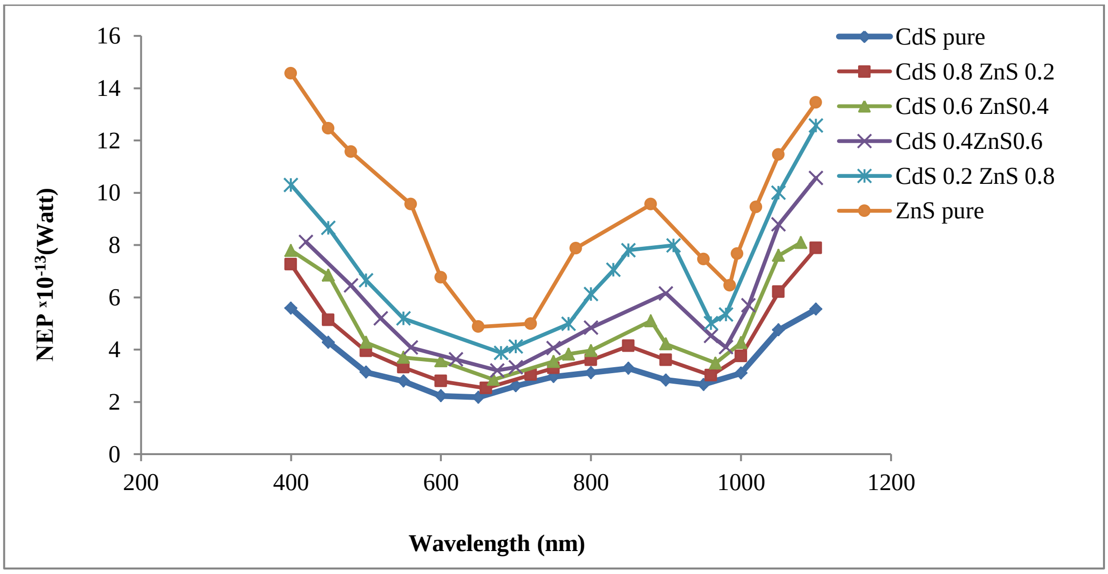


Figure (2): The variation of quantum efficiency as a function of wavelength for p-$Cd_{1-x}Zn_xS$/n-Si heterojunctionat different Vol.% of (x).

3. Noise Equivalent Power (NEP)

To find (NEP) of heterojunctionp-$Cd_{1-x}Zn_xS$/n-Si it should be calculate the dark current (I_d) by screening the illumination of detector and calculate the less current which produce at zero bias, from equation (4) the (NEP) values were calculated according to the responsivity values. The figure (3) shows noise equivalent power characteristics as a function of wavelength. From this figure we can notice that NEP increases with increasing of (x). Also we can observe that the minimum NEP occurs when R_λ has the maximum value.



Figure(3): The variation of NEP as a function of wavelength for p-$Cd_{1-x}Zn_xS$/n-Si heterojunctionat different Vol.% of (x).

4. Specific Detectivity

Figure (4) represent the specific detectivity characteristics of heterojunction (p-$Cd_{1-x}Zn_xS$/n-Si) respectively as a function of wavelength, it showed that the highest value of specific detectivity which was (4.25 $\times 10^{11} Hz^{1/2}.W^{-1}.cm$) at wavelength 650nm for the range of detection region of (CdS_{pure}), also we can notice from the figure that the D* value decreases with increasing (x). Increasing Vol.% of (x) due to increase the recombination and increase the noise generated in the detector stream centers and as a result decrease significantly the specific detectivity.

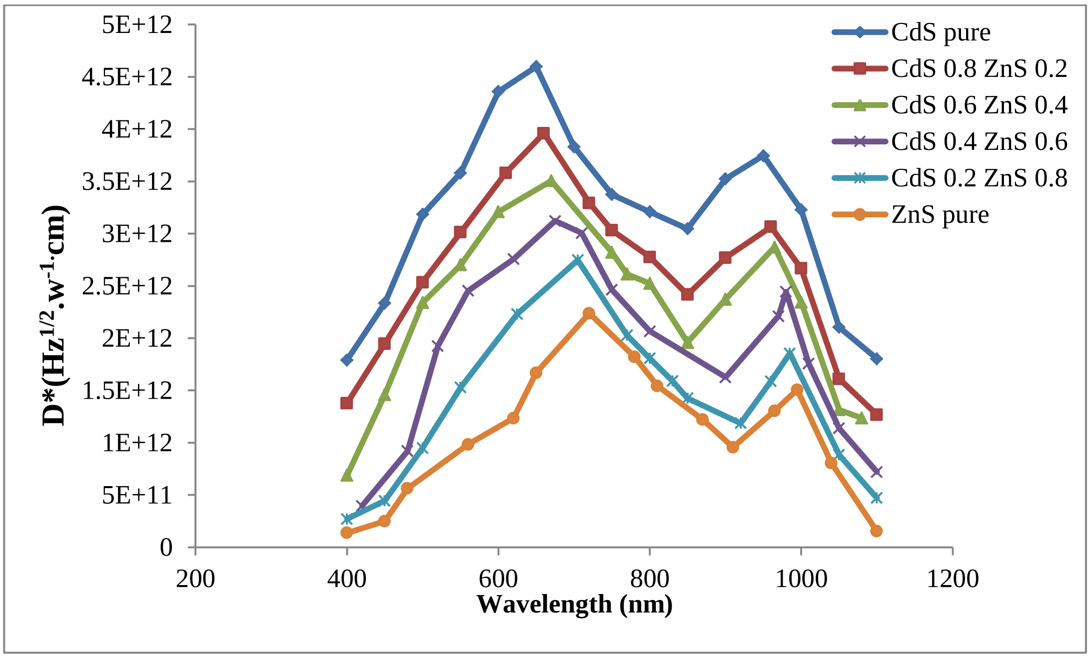


Figure (4): The variation of specific detectivity as a function of wavelength forp-$Cd_{1-x}Zn_xS$/n-Si heterojunctionat different Vol.% of (x).

Table (1): The spectral parameters for p-$Cd_{1-x}Zn_xS$/n -Si photovoltaic heterojunction for two peaks.

Sample	**λ_{peak} (nm)**	**R_λ (A/W)**	**η%**	**NEP×10^{-12} (Watt)**	**D*×10^{12} (cm.$Hz^{1/2}.W^{-1}$)**
CdS_{pure}	650	0.36	75.45	2.17	4.59
	950	0.29	44.67	2.66	3.74
$CdS_{0.8}ZnS_{0.2}$	660	0.31	70.44	2.52	3.95
	960	0.24	37.65	3.48	3.06
$CdS_{0.6}ZnS_{0.4}$	670	0.28	60.56	2.85	3.50
	965	0.22	33.56	3.49	2.87
$CdS_{0.4}ZnS_{0.6}$	675	0.24	55.57	3.20	3.12
	980	0.199	26.55	4.09	2.44
$CdS_{0.2}ZnS_{0.8}$	700	0.193	49.59	3.87	2.75
	980	0.14	22.37	5.34	1.86
ZnS_{pure}	720	0.16	43.78	4.98	2.23
	990	0.10	17.57	6.45	1.50

Conclusions

It is possible to use the hetero-junction detector (p-$Cd_{1-x}Zn_xS$/n –Si) which is manufactured in this research's conditions as a detector invisible region, part of the near IR region with wavelength range 400-1100nm. The responsively, specific and quantum efficiency decrease and shift to longer wavelength with increasing of (x).

References

1. L. Chang and K. Plog, (1985)," Molecular Beam Epitaxy and Heterostructures", Martinus Nijhoff Publishers.
2. S.Manna ,(2012), "High Efficiency Si/CdS Radial Nanowire Heterojunction Photodetectors Using Etched Si Nanowire Templates", pp 7126–7133.,J . Phys. Chem.
3. J. F. James and R. S. Sternberg, (1996) ," The Design of Optical Spectrometers", Chobman and Hall.
4. W. Budde,(1983), "Physical Detectors of Optical Radiation", Academic Press., New York 5. Jasprit Singh, (1995), "Semiconductor Optoelectronics Physics and Technology", McGraw – Hill, Inc. New York.
5. R. Kingslake, (1983), "Applied optics and optical Engineering", Academic Press., New York.
6. J. Wilson and J. F. B. Hawkes, (1983), "Optoelectronics: An Introduction", Newcastle upon Tyne Polytechnic, England, p.278.
7. R. C. Jones, (1959)," Noise in Radiation Detectors", Proc. Inst. Radio Engrs.
8. S. M. Sze,(1985), "Semiconductor Devices Physics and Technology", 2nd.ed., Wiley, New York.
9. R. J. Keges, (1980), "Optical and Infrared Detectors", Publisher: Berlin; NewYork.
10. Omran AR, Baiee MA, Juda SA, Salman JM, AlKaim AF. Removal of congo red dye from aqueous solution using a new adsorbent surface developed from aquatic plant (*Phragmites australis*). International Journal of ChemTech Research. 2016; 9(4): 334-342.

*****