Effect of annealing temperature on the Photodetector characteristic of SnS /Si hetreojunction

Alia A.A.Shehab[1], **Najiba A.AL-Hamadni**[2], **Duha M.A.Latif**[1]

[1]PhysicsDepartment, Education Faculty, Baghdad University.(IRAQ)
[2] Physics Departement, Education Faculty, AL Mustansiriya University, (IRAQ)
Corresponding author: ahmed_naji_abd@yahoo.com

Abstract— **SnS thin films of thickness, (300 nm ± 0.01) deposited by thermal evaporation with rate deposition (48±2 nm/s) on suitably cleaned silicon substrates at room temperature and then the junction were annealed at(473,573K) temperatures in vacuum for (2 h). The detector parameters such as spectral responsively, spectral detectives and quantum efficiency were studied. The responsitivety of photo detector SnS/Si is increases from**

(≈ 0.14 A/W) to greater than (0.21 A/W) after increasing annealing temperatures, quantum efficiency as a function of wavelength for devices at different annealing temperatures increased with the increased of annealing temperature and the specific detectivity was increased with increased annealing temperature.

Keywords—SnS / Si, responsivity ,Thermal evaporation ,Heterojunction.

1- Introduction

Recently, a variety of binary semiconductor especially from IV-VI and among this group of semiconductor compounds, it is considered as an important material for the development of different optoelectronic devices[1-3] because of its high photosensitivity and suitable intrinsic band gap, 1.3eV[4]. In recent years special attention has been given to the investigation of optoelectronic properties of SnS thin films in order to improve the performance of devices made of it and also for finding new applications [5,6]. SnS thin films have large optical absorption coefficient (>104cm-1).These properties enable SnS thin films to be used as an absorption layer in the fabrication of hetrojunction solar [7] SnS thin films can be fabricated by many methods such as thermal evaporation ,pulse electro deposition ,spray paralysis, SILR[8-9]. The junction in this study is grown by thermal evaporation, this method has many advantages, it is widely used because it is a simple, economic and viable technique, which produces films of good quality for device applications. In this work, an attempt has been made to prepare SnS/Si hetrojunction by thermal evaporation in order to investigate their optoelectronic properties.

2- Experimental

SnS /Si hetrojunction were prepared by thermal evaporation technique in vacuum system supplied by Edward Model [BAE 306]. The system is pumped down to a vacuum of 10-5 mbar, an electric current was passed through the boat gradually to prevent breaking the boat, when the boat temperature reached the required temperature, and the deposition process starts with constant deposition rate (48±2nm/s). This junction were taken out from the coating unit and kept in the vacuum desiccators until the measurements were made. All the samples were prepared under constant conditions (pressure, substrate temperature, rate of deposition and thickness); the main parameters that control the nature of the film properties are thickness (300±10 nm) and annealing temperature (473,573K) for 2h by using oven type (Victoreen/187-in U.S.A). The n-type Si wafer with crystal orientation (111) as a substrate for determining the electrical ,optoelectronic detector parameter of SnS/Si hetrojunction .This samples cleaned and etched Si wafers by immersing and stirring them in diluted hydroflueied acid (1:10) concentration for 1min then rinsed with distilled water for some moments, finally dried by exposed to air. The evaporation method requires using the specification of boat or filament of tungsten, molybdenum as a sample evaporation source; the suitable boat must possess high melting point and should not react with the evaporated material. The design and shape of the boat must also be selected depending upon the type of material. A molybdenum boat of melting point 2895K was used to evaporate SnS on Si substrate. It has rectangular solid shape with appropriate depth to prevent material sputtering during evaporation process.

3- Results and discussion

3.1 Specific Responstivety (R_λ)

The responsivity is an important parameter that is usually specified by the manufacturer knowledge of the responsivity allows the user to determine how mach detector signal will be available for a specific application. Moreover the units of responsivity are either A/W or V/W, depending on whether the output is an electric current or voltage. The responsively Rλ is given by [10]

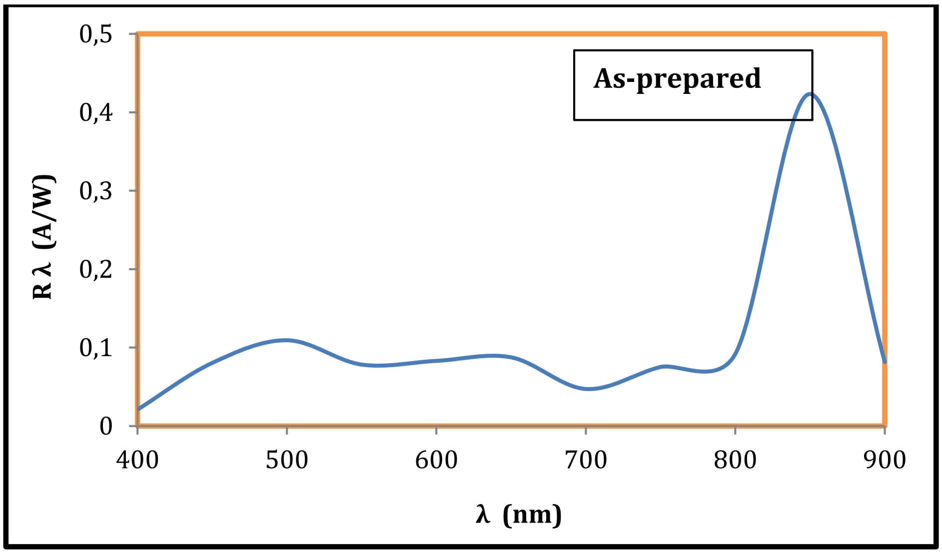
$$R_{\lambda} = \frac{I_{Ph}}{P_{in}(\lambda)} \quad (1)$$

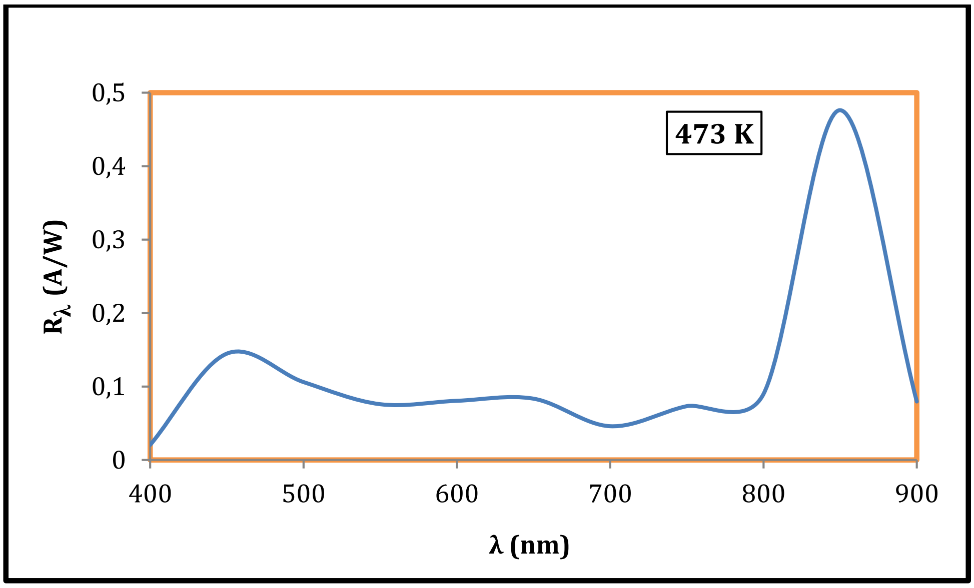
Where I_{ph}: is the photocurrent.

$P_{in}(\lambda)$: is the input power.

Spectral responstivety of photo detector is very important parameter to evaluate the performance of any photo detector. It is investigated in the wavelength range of (400–900 nm) with (5V) voltage bias Fig. (1) Displays the responstivety as a function of wavelength for SnS/Si at different annealing temperatures

It is clear from these Figures that there are two regions of peak response, the first region is located at visible region and the second located at NIR. All the samples display that very identical spectral responses and the differences appeared to be in the amplitude, with different annealing temperatures. The result of responsivity means that the portion of light with higher energy, such as (400 –500 nm), is absorbed by SnS film (region 1) and the portion of light with lower energy, such as (800 – 900 nm) (region 2), can completely incident into Si substrate and is absorbed. These results are due to the absorption edges of SnS and Si. From the responsively of SnS/Si as-prepared is about (0.11 A/W). The responstivety of photo detector SnS/Si is increases from (≈0.14 A/W) to greater than (0.21 A/W) after increasing annealing temperature.





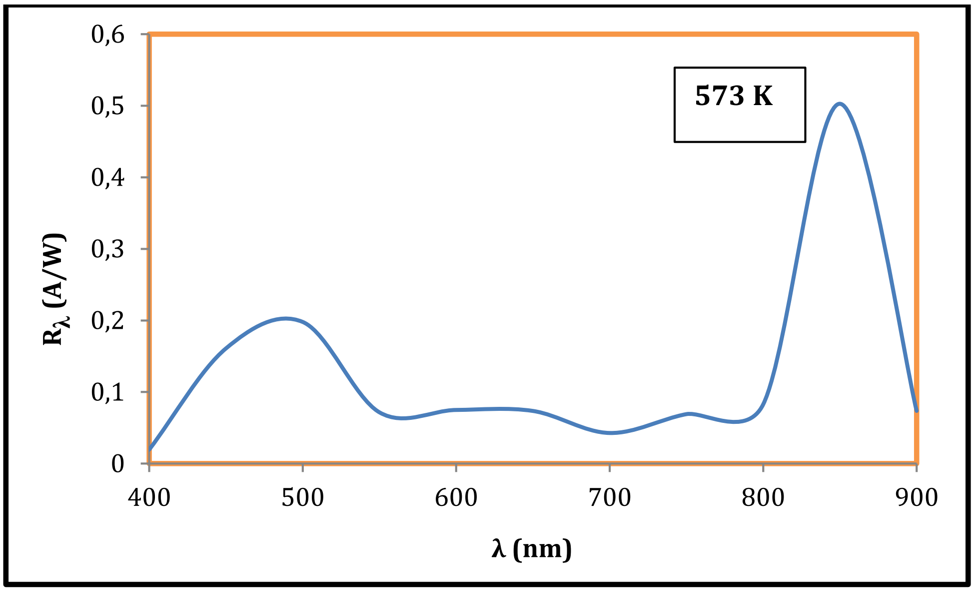


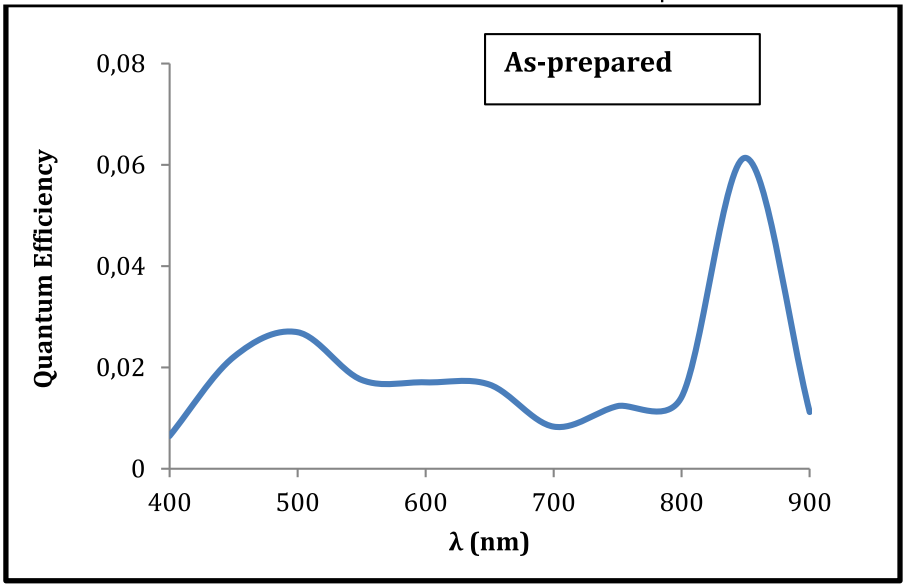
Fig.(1) Responsivity for SnS/Si at different annealing temperatures

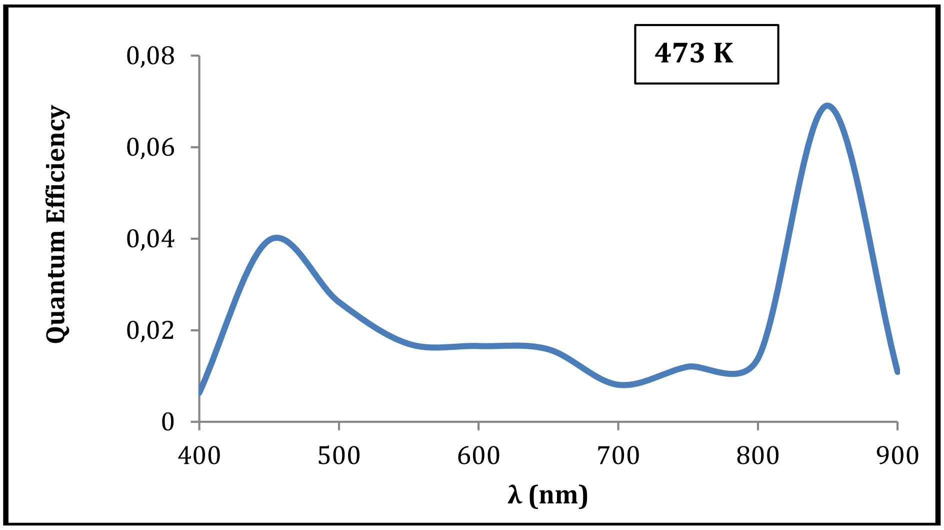
3.2 Quantum Efficiency (QE)

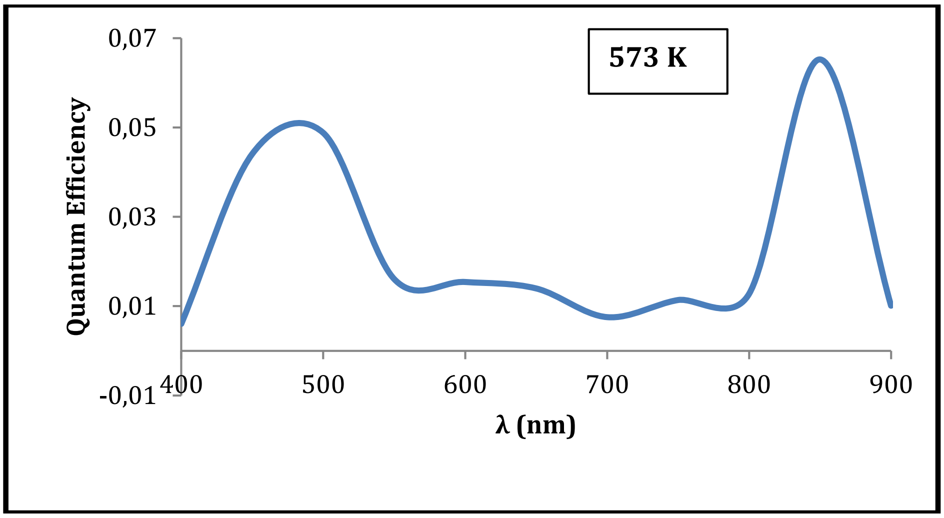
Quantum efficiency can be defined as the ratio of the current generated optically to the number of incident photon, or in the other words it is the number of electron-hole pairs generated per incident photons. The quantum efficiency is basically another way of expressing the effectiveness of the incident optical energy for producing an output of electrical current, the quantum efficiency Q_E (in percent) may be related to the responsively by the equation:[58]

$$Q_E = 100\, R(\lambda)\ (1.24 / \lambda) \qquad (2)$$

R (λ): is the responsivity (in amperes per watt) of the detector at wavelength λ (nm) [11]. Fig. (2) for SnS/ Si heterostructures indicate that the variation of quantum efficiency as a function of wavelength for devices at different annealing temperatures. The increase in the photocurrent is attributed to the same reasons of responsive.







Fig(2):Quantum efficiency of SnS/Si at different annealing temperatures

3.3 Specific Detectivity (D*)

Specific directivity(D*): can be defined as the detector signal to noise ratio when 1 Watt of optical power is incident on the detector with optical area 1 cm2 and the noise is measured with a band width of 1 Hz . It is used because it is normally dependent of the size of the detector and the bandwidth of the measurement circuit the specific directivity, D*is determined using the following equation [12]

$$D^* = R_\lambda \frac{A^{1/2}.\Delta f^{1/2}}{I_n} \qquad (3)$$

$$I_n = \sqrt{2eI_d} \qquad (4)$$

Where Δf: is the noise bandwidth, A0: is the area of the sample and In: is the noise current e: is the electron charge Id :is the dark current

The detectivity of a photo detector can be defined as the minimum detectable power. Figure (3) shows the specific directivity as a function of wavelength for (SnS/Si) photo detector. This figur reveled the variation of detectivity with wavelength. It is clear from Figs.(3) that increases in annealing temperatures increasing in detectivity.This figur shows that the detectivity depend directly on responstivety.The maximum D* was found to be (0.122×1012W-1cm Hz1/2) at λ = 850 nm for Si detectivity which increases after increasing the annealing temperatures and the other region is maximum D*was found to be (0.05x1012W-1cm Hz1/2) at λ = 490 nm at (573 K) temperature annealing.

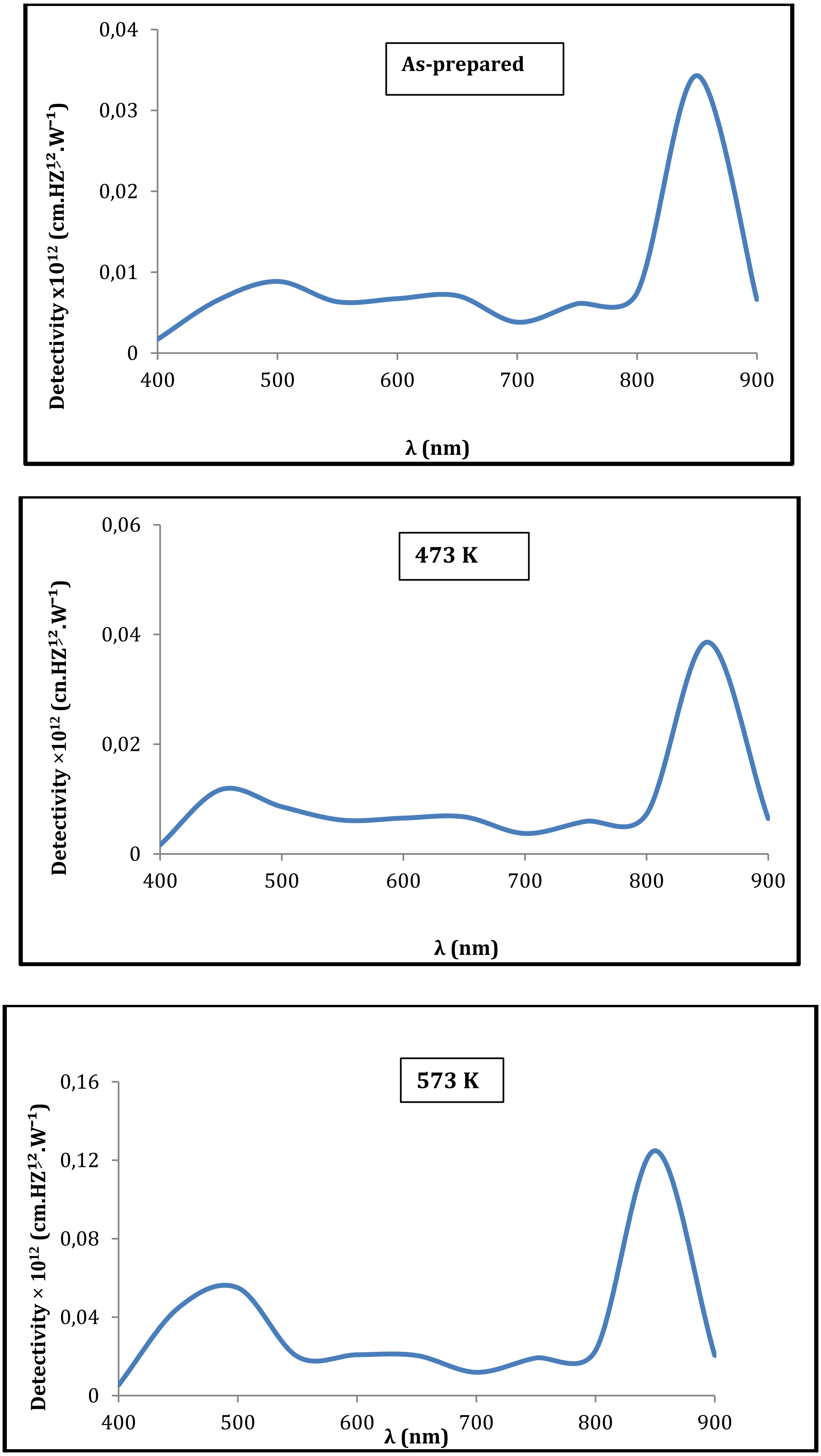


Fig.(3)Detictivity of SnS /Si at different annealing temperatures.

4- Conclusion

SnS/Si hetrojunction were grown by a thermal evaporation technique at room temperature and annealing with (473 K, 573 K) temperatures. By increasing annealing temperature the specific detectivety properties of this junction offered the best results, increases with increasing temperatures. The maximum spectral responsivity (R_{λ}) of SnS/Si photodetector at different annealing temperatures for 573 K the benefits of using the SnS/Si and the maximum specific detectivity (D*) was found to be due to 573 K annealing temperature. The main conclusion of this work concerns the benefits of using the SnS/Si junction for solar cell applications.

References

[1] P.K.Kalita, B.K.Sarma, H.L.Das; Bull.Mater.Sci., 26, 613 (2003).

[2] C.Baban, G.G.Rusu, G.I.Rusu, J. Phys. Condens. Mater., 12, 7687 (2000).

[3] K.C. Sathyalatha, S.Uthanna, P.Jayaramareddy; Thin Solid Films, 174, 233 (1989).

[4]K.N.Shreekanthan,B.V.Rajendra,V.B. Kasturi, G. K. Shivakumar, ryst.Res.Technol., 38, 30,(2003).

[5]L.Ion,S.Antohe,M.Popescu,F.Scarlat, F. Sava, F.Ionescu; J. Optoelectron. Adv. Mater., 6, 113, (2004).

[6]P.P.Hankare,V.M.Bhuse,K.M.Garadkar,S.D.Delekar,I.S.Mulla;Semicond.Sci.Technol., 19, 70,(2004).

[7] R. B. Kale , C. D .Lokhande, Semicond.Sci.Technol., 20, 1, (2005).

[8] C.Baban, G.I.Rusu, P.Prepelita; J.Optoelectron.Adv.Materials, 7, 817 (2005)

[9] I.H.Khan, L.I.Maissel, R.Glang (Eds); Hand Book of Thin Film Technology,

[10] J.D. Vincent, "Fundamentals of Infrared Detector Operating and Testing",John Wiley and Sons, New York, (1990).

[11] S .M. Sze and K. N. Kwok,"Physics of Semiconductor Devices" by John Wiley & Sons, Inc. 3rd Ed. U.S.A, (2007) 8-58.

[12] J. Karger, " Diffusion in Condensed Matter "; Vieweg & Sohn Verlagsgesell; Germany, (1998).