Indian Journal of Science and Technology Vol. 4 No. 4 (April 2011) ISSN: 0974- 6846

Fabrication and study zinc sulfide schottky barrier detectors

Salma M. Shaban, Nada M. Saeed* and Raad M. S. AL-Haddad
Dept. of physics, College of science, University of Baghdad, Baghdad, Iraq
nadaalkhanchi@yahoo.com*

Abstract

Schottky barrier photodiode of zinc sulfide (ZnS) thin film have been fabricated by thermal evaporation method. The n-type ZnS thin films of thickness 400 nm were deposited onto glass substrates at 150°C. The photodiode was form by evaporation of gold thin films on the n-type ZnS films and evaluated as UV near visible detectors. ZnS thin films were checked by using X-ray diffraction (XRD); the result shows that the films were polycrystalline. The lattice constant for ZnS films was calculated and it was 5.41A°. The absolute quantum efficiency of the photodiode was measured for wavelengths between 200-600 nm. The responsivety of the prepared photodiodes of different thickness of gold thin films (50, 80 & 100 nm) was measured for wavelengths at the range as mentioned above. These detectors have negligible response to wavelengths longer than 340 nm which correspond to energies less than the band gap of the zinc sulfide. Finally the barrier height of diode was measured by the C-V method and found as low as 1.9 V.

Keywords: Schottky barrier, thermal evaporation method, zinc sulfide, gold thin films.

Introduction

Zinc sulphide (ZnS) is an important II-VI group semiconductor with a large direct band gap of 3.6 eV near UV region, ZnS thin films have a high refractive index of 2.27 at 1 μm and high transmittance in the visible range (Park *et al.,* 2002; Monroy *et al.,* 2003). It is an important device material for the detection, emission and modulation of visible and near ultraviolet light (Antony *et al.,* 2005). ZnS is highly suitable as a window layer in hetrojunction photovoltaic solar cells; because the wide band decreases the window absorption loses and improves the short circuit current of the cell (Kumar *et al.,* 2008). Ultra-violet photodetectors respond only to ultraviolet light with high discrimination against infrared radiation can find applications in areas such as fire detection, flame combustion control, UV astronomy, industrial and medical applications as well as in a number of personal healthcare consumer products. In recent years, there has been increasing interest in developing GaAlN alloy, SiC, diamond, and a number of wide band gap II-VI thin film based visible-blind and solar blind UV detectors (Fathy *et al.,* 2004).

The structure of such thin films was obtained using X-ray diffraction technique. Zinc sulfide has two types of crystal structures; hexagonal wurtzite and cubic zinc blende (Cheng *et al.,* 2003; Li *et al.,* 2003). Thin films of ZnS were prepared using many deposition techniques, the optical properties of the prepared film depend strongly on the fabrication technique (Prathap *et al.* 2008). The Schottky barrier photodiode is inherently a fast, efficient detector of radiation of energy greater than the band gap of the semiconductor. This radiation will generate hole-electron pairs within the depletion region of the barrier where they are collected efficiently and rapidly by the built-in field.

Kushkul (2001) studied the electrical and optical propertied of ZnS thin films deposited by thermal evaporation and the effect of their thicknesses on the photovoltaic p-n junction (silicon photocell). He found that the optical energy gap is in the range (3.2-3.3) eV for different thicknesses (100-300 nm). The thin film is n-type and the hall coefficient decreases with increasing thickness and the structure was polycrystalline. Richardson and Baerish (1968) studied ZnS Schottky barrier ultra- violet detectors deposited by thermal evaporation. The barrier height of Ag-ZnS diode were measured by the C-V method and found to be as low as 1.9 V. The spectral response of Ag-ZnS diode was shown at 322.5 nm with thickness 79 nm and quantum efficiency at this thickness was 0.45.

Kumar *et al.* (2006) studied photoconductive response of ZnS films prepared by vacuum evaporation. They found that ZnS films have energy gap of 3.5 eV and the conductivity of the films depends on the temperature.

The spectral responsively is regarded as an important parameter of the detector; it determines the efficiency for detection at a range of wavelength and determines the spectral range which the detector uses for detection .The spectral response is given by the equation:

$R_\lambda = I_{ph}/P_{in}$ (1) or $R_\lambda = V/P_{in}$ (2)

Where R_λ is the responsively-dependent wavelength (λ), I_{ph} is the output photocurrent, V is the output Voltage, and P_{in} is the input power.

Equations (6 & 7) are used when the output is a current and voltage respectively.

For photoelectric detector whose output is a current, the quantum efficiency can be computed from current responsively:

$\eta_\lambda = R_\lambda hc/q\lambda = 1.24\, R_\lambda/\lambda$ (3)

Where η_λ is the quantum efficiency-dependent wavelength (λ), h is blank constant and q is electron charge.

For many applications one requires a photodetector with high quantum efficiency in the U.V, but little sensitivity to visible and no respond to I.R. radiation. The schottky barrier of zinc sulphide, which has a band gap of 3.68 eV, satisfied these requirements.

Experimental part

Polycrystalline zinc sulphide (ZnS) compound with a purity of 99.999% was used to prepare n-type ZnS thin films by thermal evaporation method, n-type thin films were deposited on glass substrates at 150°C. Thin films of gold of thicknesses (50, 80 & 100 nm) were deposited on ZnS thin films at room temperature to obtain Schottky barrier photodiode by the previous method. Each of gold and ZnS were evaporated from molybdenum boat, (a molybdenum boat was used as the source holder), and the pressure inside the chamber was better than 2×10^{-5} m bar, the distance between the boat and the substrate was 15 cm for ZnS thin films and 9 cm for gold thin films. The prepared films were analyzed by X-ray diffraction technique for structural analysis; this technique has the following information:

Source of CuK_α radiation, scanning angle (20˚-70˚).

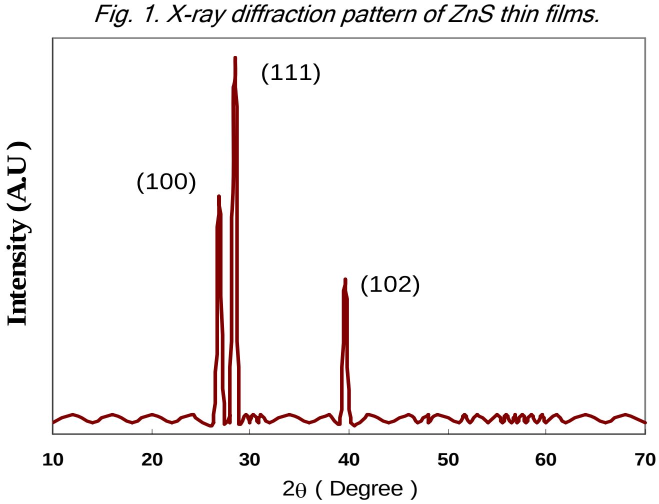
Suitable masks were made from aluminum foil for hall measurement; the sensitive digital electrometer (Kiethley model 610 B) was used for this measurement. Two experimental methods were used for thickness measurements; the weighting method (which gives an approximate value for the thickness) and the optical interference fringes method with an error of ± 0.4%. The spectral response of the photodiodes was measured with a lamb grating monochrometer. The same electrometer was used to measure the short circuit photocurrent of the diode at zero bias. The absolute quantum efficiency of the diode was then measured by the C-V method.

Results and discussion

X-Ray diffraction results for ZnS thin films

X-ray diffraction pattern was studied for the prepared ZnS thin films, the results show that the film was polycrystalline, as show in Fig. 1. The X-ray pattern of the films was found to exhibit three diffraction sharp peaks associated with (100) and (102) reflections for the hexagonal structure and (111) reflection for the cubic structure of which the intensity of the (111) orientation is predominant.

Fig. 1. X-ray diffraction pattern of ZnS thin films.



The d-values were calculated by calculating θ values from the peaks of the X-ray spectrum by using Bragg's relation:

$2d\sin\theta = n\lambda$

n=1 in present study and λ= 1.54045 nm for CuKα.

These d values were compared with the standard ASTM data to confirm the structure of ZnS, as listed in Table 1.

Table 1. X-ray diffraction data for ZnS compound as thin films.

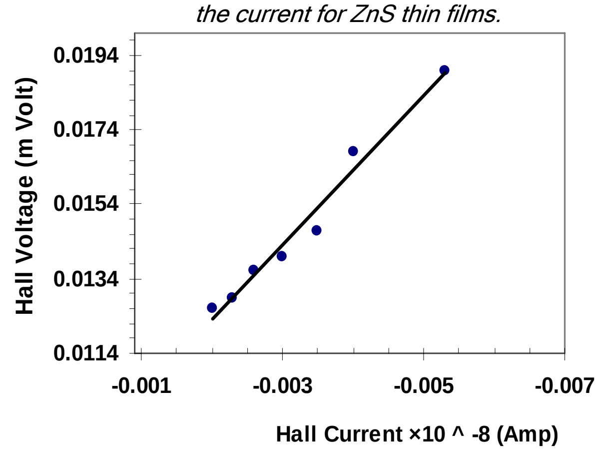
(hkl)	d(ASTM) (A°)	D(exp) (A°)	2 Θ (exp)	I/I_o (exp)	Type
(100)	3.309	3.311	26.89	60	Hexagonal
(111)	3.128	3.124	28.54	98	Cubic
(102)	2.273	2.277	39.53	39	Hexagonal

The lattice constant of ZnS thin films was calculated it was 5.413 A°; (the standard value of the lattice constant is 5.42 A°). The calculated value is in agreement with the value estimated by Seeger (1997) and Ben *et al*, (2006) when they used magnetic beam evaporation (MBE) method for prepared ZnS thin films.

Hall effect & hall results for ZnS thin films

Carrier concentration and hall mobility have been determined from hall measurements for ZnS thin film. Fig. 2 shows the plot of hall voltage versus the current for ZnS thin films, by using the slope of the figure and the fallowing equation:

Fig. 2. Hall voltage as a function of the current for ZnS thin films.



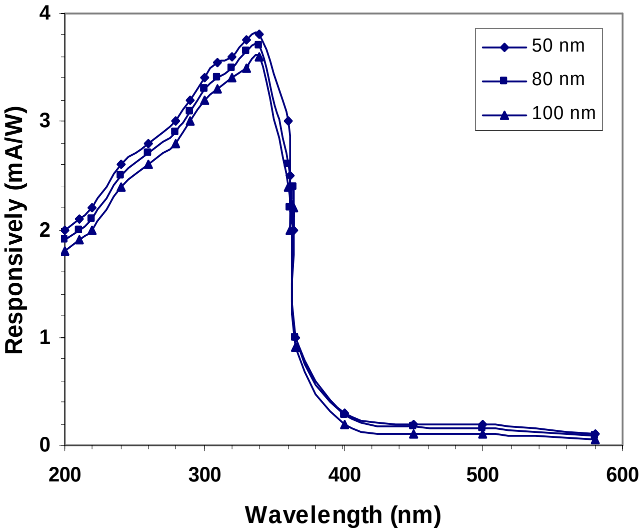
$$R_H = \frac{V_H}{I} \cdot \frac{t}{B}$$

Hall coefficient (R_H) was calculated, its value pointed that the films was n-type, the carrier concentration was estimated as $2\times10^{13}(cm^{-3})$.

The barrier height measurements

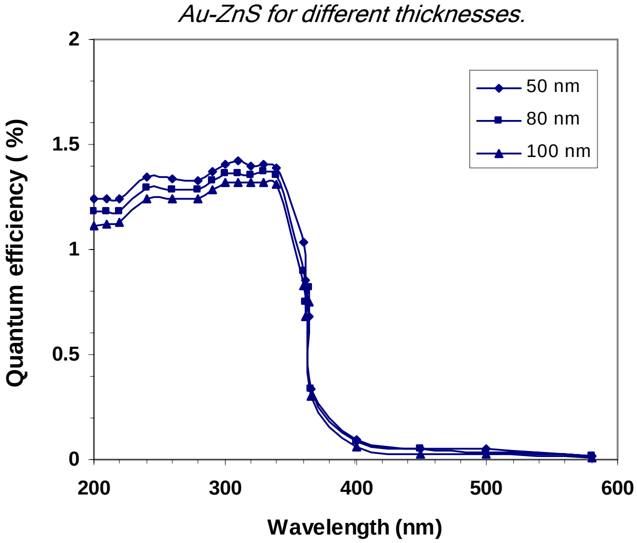
The barrier height of the diode was measured by the C-V method and was found to be as low as 1.9 V. Fig. 3 shows the spectral response of three Au-ZnS diodes with different thicknesses of Au films, from the figure; the responsively decreases as the increase of the film thickness.

Fig. 3. Spectral response of Au-ZnS diode of Au different thicknesses.



The quantum efficiency was calculated from eqn. 3 . Fig. 4 shows the quantum efficiency as a function of wavelength. From the figure the quantum efficiency decreases with the decrease in wavelength and this is due to the increase of reflection loss at the Au-ZnS surface. The thickness of the thin films is one of the most important parameter which affects the physical properties of the films (Mihaela & Rusu, 2002).

Fig. 4. The quantum efficiency of Au-ZnS for different thicknesses.



Conclusion

Schottky barrier Au-ZnS photodiode was successfully fabricated and it found as UV -near visible detectors; the third trying in preparation was good. The barrier height of the diode was measured and it was found to be as low as 1.9 V, the quantum efficiency decreases with the decrease in wavelength. The responsivety of the diodes decreases as the increase of the film thickness.

References

1. Antony A, Mirali KV, Manoj R and Jayaraj MK (2005) Growth of ZnS thin films obtained by chemical spray pyrolysis. *Mater. Chem. Phys*. 90, 105-106.
2. Ben Nasir T, Kamoun N, Kanzari M, Bennaceur R (2006) Effect of pH on the properties of ZnS thin films grown by chemical bath deposition. *Thin Solid Films.* 500, 2.
3. Cheng Fan J, Wang DB, Liu H, Zhang YC and Yan H (2003) Chemical bath deposition of crystalline ZnS thin films. *Semicond. Sci. Technol.* 18, 676-679.
4. Fathy N, Kobayashi R and Ichimura M (2004) Photoelectrical properties of ZnS thin films. *Mater. Sci. Engg*. 107, 270-271.
5. Kumar P, Kumar A, Dixit PN and Sharma TP (2006) Optical, structural and electrical properties of Zinc Sulphide vacuum evaporated thin film. Indian J. Pure & Applide Physics. 44, 690-693.
6. Kumar V, Sharma MK, Gaur J and Sharma TP (2008) Polycrystalline ZnS thin films by screen printing method and its characterization. *Chalcogenide Lett*. 5 (11), 289-295.
7. Kushkul EN (2001) The effect of ZnS thickness on the P-n junction. *M. Sc. Thesis*, University of Mustansiriyah.
8. Li D, Ma J, Ch. Moore and Wang ZL (2003) Nanobelts, nanocombs and nanowindmills of Wurtzite ZnS. *Adv. Mater*. 15, 228-231.
9. Mihaela G and Rusu G (2002) Detection and quantification of GMO and sequencing of the DNA amplified products. *Appl. Surf. Sci*. 162, 491-492.
10. Monroy E, Omnes F and Calle F (2003) Structure-Property-Function Relationships in Nanoscale Oxide sensors. Abase study on Zinc Oxide. *Semicond. Sci. Technol*. 18, 31-33.
11. Park W, King JS, Neff CW, Liddell C and Summers C (2002) ZnS-based photonic crystals *Phys. Status Solid.* 229, 949-960.
12. Prathap P,' Revathi N, Venkata Subbaiah YP and Ramakrishna Reddy KT (2008) Thickness effect on the microstructure, morphology and optoelectronic properties of ZnS films. *J.Physics: Condensed Matter*. 20 (3). 35205.
13. Richardson JR and Baertsch RD (1968) Zinc Sulfide schottky barrier UV detectors. *Solide State Elec*. 12, 392-393.
14. Seeger K (1997) Semiconductor Physics. Springer, Berlin, Germany. pp: 207-208.