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Study of Optoelectronic Properties CdS-Si Heterojunction Prepared by Chemical Bath Deposition Method

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ABSTRACT

CdS-Si heterojunction detector has been prepared by chemical bath deposition method . Structure properties of these films was characterized by X-ray diffraction .CdS films deposited have polycrystalline structure cubic(zinc blende) and hexagonal. The average grain size is 45 nm .The optical properties of the CdS films have highly transmittance in visible region of spectrum and reach to more than 80% with a wide band gap of 2.44 eV .Electrical properties of CdS-Si heterojunction have been investigated. The I-V characteristics under dark condition depict that good rectification behavior and exponential relationship for forward current biasing. The C-V measurements have shown that the heterojunction were of abrupt type and the build-in potential equal to 1.75V. The optoelectronic characteristics shows that CdS-Si detector has good spectral responsivity in the visible and the near infrared and show high sensitivity, in comparison with the conventional p-n silicon detectors.

Introduction

The heterojunction has been the subject of active research on many devices such as transistor, thyristors, semiconductor lasers, photodetectors, and solar cells [1].

So far, interest in cadmium sulfide (CdS), having an optical band gap of 2.42 eV has increased due to its application in various strategic fields, such as in photovoltaic solar cells and electronic and optoelectronic devices [2-5].There are various methods employed for deposition the CdS thin films such as spray pyrolysis [6], pulsed laser deposition [7], chemical vapour deposition [8], vacuum evaporation [9], electro deposition [10], sputtering [11], successive ionic layer adsorption reaction [12] and chemical bath deposition [13].

Chemical bath deposition (CBD) is known to be a simple, low temperature inexpensive and large-area deposition technique. It has been used in the deposition of CdS semiconductor thin films since the 1960s [14,15].The CBD method being less expensive than other thin film deposition methods allows for the manufacture of relatively low cost devices especially light detectors and light energy conversion cells [16].

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Deposition of CdS using CBD is based on the slow release of Cd^{2+} ions and S^{2-} ions in an aqueous alkaline bath and the subsequent condensation of these ions on substrates suitably mounted in the bath. The slow release of Cd^{2+} ions is achieved by adding a complexing agent (ligand) to the Cd salt to form some cadmium complex species which, upon dissociation, results in the release of small concentrations of Cd^{2+} ions. The S^{2-} ions are supplied by the decomposition of thiourea or sodium thiosulfate[17].In the present study, the fabrication and characterization of anisotype CdS-Si heterojunction detector prepared by CBD method were reported..

Experimental

CdS thin film was deposited on both silicon and a cleaned glass substrate at the same conditions by the chemical bath deposition method. A CdS-Si heterojunction detector was fabricated on a p-type silicon wafer. Prior to the deposition the CdS film, the silicon wafer was immersed in diluted HF solution and then washed with deionized water to remove the native oxide. Aluminum contacts of 100 nm thickness were formed on the CdS film and the back surface of silicon by thermal evaporation. The glass substrates were cleaned with soft cotton and washed with double

distilled water and dried in air. The CdS films was grown on Si and glass substrate by using the cadmium nitrate salt [$Cd(NO_3)_2 .4H_2O$] wath a molarity of 0.1 M as a source of cadmium ions(Cd^{+2}) and 0.1 M thiourea [$SC(NH_2)_2$] as a source of sulphide ions(S^{2-}). Ammonium hydroxide solution (NH_4OH) 25 % was added slowly to adjust pH at 11 .The solution was stirred to ensure homogeneous dissolve for about 5 minutes. The bath temperature was kept at 80 °C for 1hrs and under unstirred condition. At the end of deposition, the film surface was non homogeneous and granular. Thus, the film was washed with de-ionized water to remove loosely adherent powder and dried in N_2 atmosphere. After cleaning, the film surface becomes smooth and specular. The films were annealed in vacuum at 300° for 2 hrs .The thickness of the film was determined with a Mettler Toledo MX5 microbalance using the weighing method with the relation t=m/(ρ×A) where, *m* is the mass of the film deposition on the substrate in gm; *A* the area of the deposited film in cm^2 and ρ the density of the deposited material (CdS =4.089 g/cm^3) in bulk form[19]. The thickness of the CdS film was found to be approximately 600 nm.

The X-ray diffraction(XRD) analysis was carried out using X-ray 6000(Shimadzu) diffractometer with Cuk_α radiation (λ=1.541 Å) at 40 kV .The optical transmission spectra were investigated by UV-Visible Spectrophotometer (Cintra 5) GBC-Astrural).Dark I-V measurements were done by using a DC power supply and Keithley electrometer.

The illuminated I-V characteristics were measured under a tungsten-halogen lamp light. C-V measurements at a frequency of 100 kHz were made using an (hp) LCZ meter. All measurements were carried out at room temperature. The spectral measurements of CdS-Si heterojunction detector were made by using a monochromator (optometics U.S.A.Inc.edmund industrial opticals model-04 53954) in the range (400- 1100)nm. The results were calibrated by measuring the power of each spectral line using a standard power meter.

Results and discussion

X-Ray Diffraction

Fig.1 shown X-ray diffraction pattern of CdS thin films deposited on glass substrate. From the diffraction pattern, it can be seen that the diffraction peak is sharp and well defined indicating that the film is single crystalline in nature. The diffraction peak existed at 2θ = 26.6° corresponding to either the (002) hexagonal or the (111) cubic planes. This value of 2θ and its crystal planes are comparable with standard data from CdS matches well (JCPDS file no .79-0043). Similar results have been observe by CBD as reported in literatures [19,20].

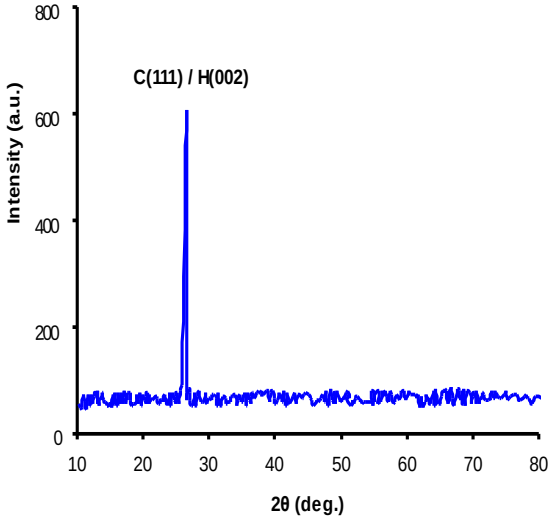

Fig.(1).The X-ray diffraction patterns of CdS thin films.

The grain size (D) of CdS film was estimated using Debye-Scherrer's formula, [21]

$$D = \frac{0.9\lambda}{\beta\cos\theta} \quad \text{..... (1)}$$

where λ is the X-ray wavelength ,β is the full-width at half-maximum (FWHM) of the peak, and θ is the reflection angle. The grain size of the CdS film was found to be 45.387 nm for the (111) direction. These result agree with those of many studies[17,22].

Optical Properties

Figure 2 shown the optical transmittance of the CdS film deposited on the glass substrate. A high average transmittance of over 80% in the visible region was observed. The direct optical band gap of the CdS film can be calculated by the following relation [23]:

$$(\alpha h\nu) = A(h\nu - E_g)^{1/2} \text{.....(2)}$$

where *hν* is the photon energy, *α* is the absorption coefficient, E_g is the optical band gap and *A* is a constant relative to the material. In order to calculate the optical band gap of the CdS film, the measured transmittance (*T*) was transformed to the absorption coefficient (*α*) using the relation $\alpha = (1/d)\ \ln(1/T)$, where *d* is the thickness of the film and we plotted the

curve of $(\alpha hv)^2$ versus hv of the CdS film, as shown in figure 3. The optical band gap of the CdS film was determined from figure 3 and was found to be 2.44 eV. The obtained optical band gap of CdS in this work is in agreement with the known range of values (2.42-2.5 eV) [24-26].

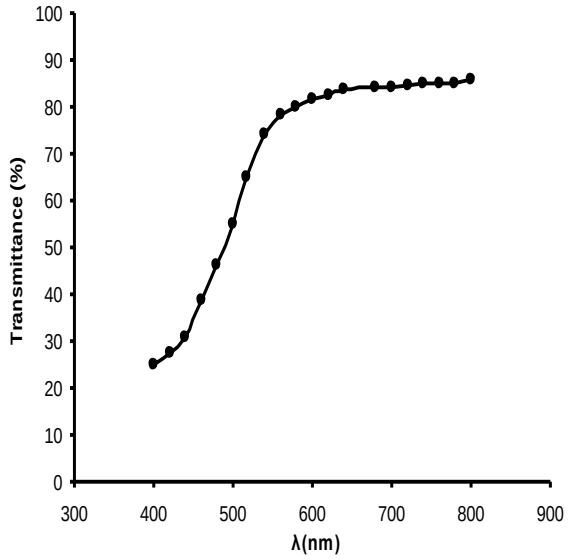

Fig.(2). The optical transmission spectra as a function of wavelength for CdS thin films .

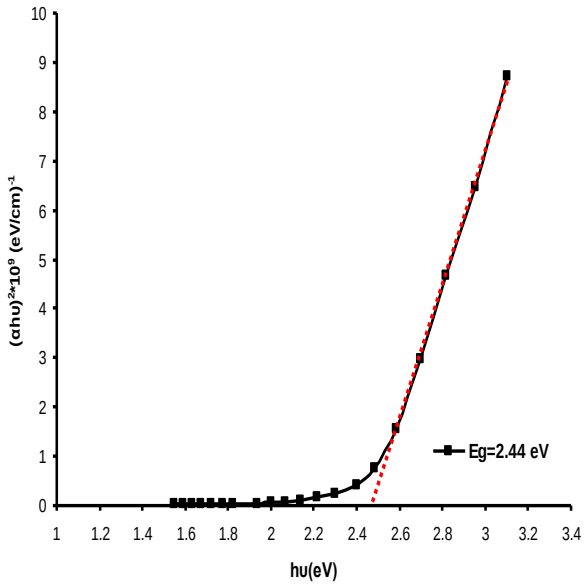

Fig.(3).A plots of (αhυ)2 versus (hυ) of CdS thin films.

Electrical characteristics of CdS /Si heterojunction

The forward and reverse bias voltage under dark condition of CdS-Si heterojunction is shown in Fig.(4). In forward bias current increase with voltage as expected , but reverse bias , the current was found to increase slowly with voltage (soft breakdown) without any sharp breakdown [27] .This result agree with [28]. The forward current tends to saturate at Vf >3V due to series resistance originating from a large value of mismatch lattice constant between CdS and Si (7%). The I-V under illumination condition of different illumination power of the sample is shown in Fig.(5). Increasing intensity of light result in the increase in the photocurrent, indicating good linearity characteristics.

The Fig.(6) shown the C^{-2}-V plot, the decrease in the capacitance with increase the bias voltage because of the increase the width of the depletion region (increase absorption area).The junction of this heterojunction is abrupt and the built-in – potential V_{bi} was determined from the figure where [at $C^{-2}=0$] and found to be 1.75 eV.

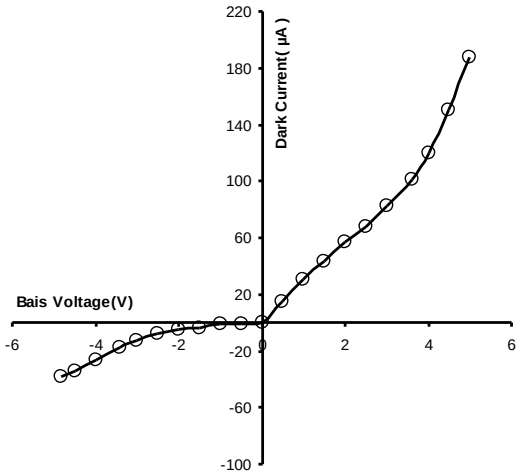

Fig. (4).Current-voltage for characteristics CdS-Si heterojunction.

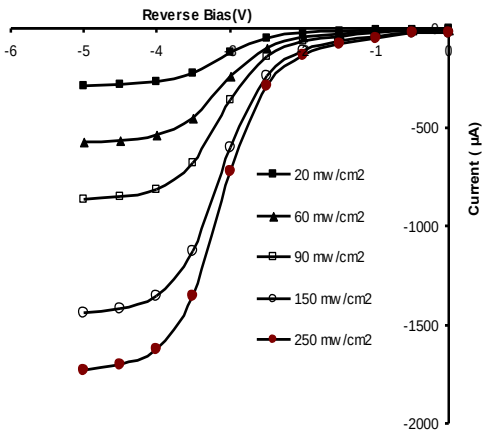

Fig. (5).Current-voltage in illumination condition for characteristics CdS-Si heterojunction.

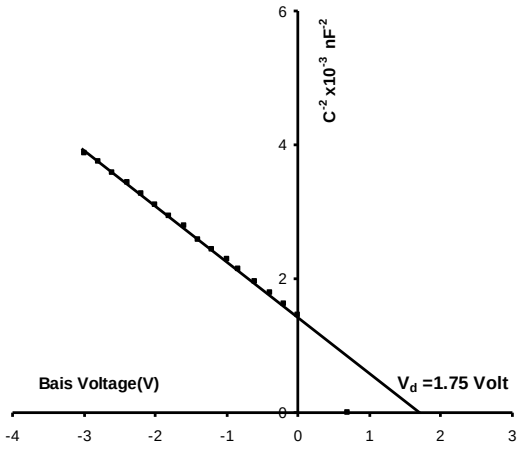

Fig.(6).C-2 versus bias voltage for characteristics CdS-Si heterojunction.

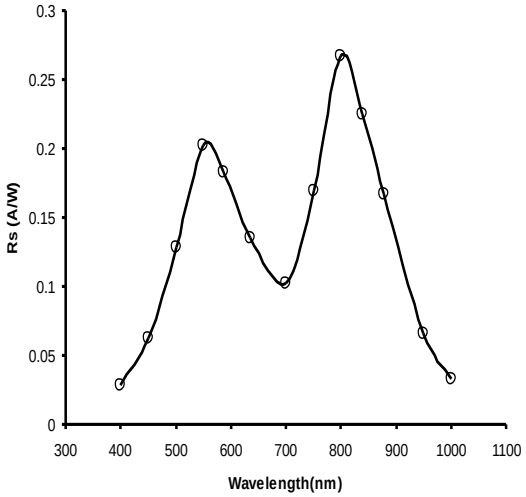

Fig. (7) .Responsivity as function of the wavelength of CdS -Si detector.

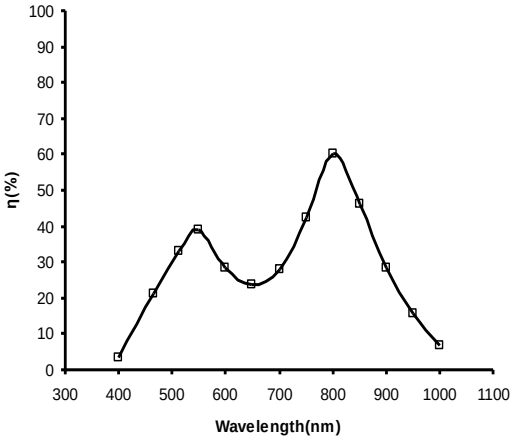

Fig. (8).The quantum efficiency as function of wavelength of CdS -Si detector.

Optoelectronic Characteristics of CdS -Si Detector

The responsivity R_s as function of wavelength for spectral range (400-1000)nm of the detector at 2V reverse bias is depicted in Fig. 7. The responsivity can be calculated from the following relationship[28]:

$$R_S = \frac{I_{ph}}{P_{inc}} \quad \text{.....(3)}$$

Where I_{ph} is the photocurrent, and P_{inc} is the incident power.

From fig.7 we observe two peaks first peak at region 550±20 nm(this peak due to the absorb of light in CdS through band to band absorption) while second region at 800±20 nm (which was due to the Si bandgap)[29] .The responsivity of CdS-Si detector was 0.26A/W at wavelength 800 nm .The CdS-Si has high responsivity compared with other hetrojunction such as Bi_2O_3/Si [30] and little than Cu_2O/Si [1] .The quantum efficiency as function of wavelengths was shown in fig.8.The quantum efficiency peak was 60% at wavelength 800 nm.

Conclusions

CdS-Si was prepared by chemical bath deposition technique . The XRD measurements indicate that the structure of the CdS thin films is the (002) hexagonal or the (111) cubic planes cubic(zinc blende).The CdS films has flat surface, a high average transmittance over 80% in the visible region with the presence of wide band gap of 2.44 eV, is a promising material to be used in photovoltaic devices, solar cells and detectors. CdS-Si heterojunction is abrupt type with a built-in-potential equal to 1.75 eV.CdS-Si has two peaks first peak at region 550±20nm and second region at 800±20 nm .The quantum efficiency peak was 60% at wavelength 800 nm.

References

[1] Yahiya Khaled. Z., Daood Yasmeen .Z., Ahmed Saria D.,(2007) .J. Eng. & Technology,25,2,176-182.
[2] Weinhardt L et al (2003).Appl. Phys. Lett. 82, 571.
[3] Didden, H.Battjes,R.Machunze,B.Dam, R.Van de Krol,(2011).Appl. Physics ,110,033717 .
[4] Bugelman M. ,Nollet P.,(2005) .Solid State Ionics, 176 ,2171.
[5] Pradhan B. , Pal A.,(2004).Sol. Energy Mater. Sol. Cells,81, 469.
[6] Shadia J. Ikhmayies , Riyad N. Ahmad-Bitar,(2010). Jordan Journal of Mechanical and Industrial Engineering,4,1,111-116.
[7] Kwork H.S., Zheng J.P., Witanachchi S., Attocks P., Shi L., Ying Q.Y., Wang X.W. , Shaw D.T., (1998).Appl. Phys. Lett. 52 1095
[8] Birkmire R.W., Mc Candless B.E. , Hegedus S.S., (1992).Sol. Energy ,12, 45 .
[9] Mahmoud S.A, Ibrahim A.A. , Ismail Raid. A., (2000).Thin Solid Films, 372, 144 .
[10] Morris G. C., Tottszer A. , Das S. K. (1991) .Mater. Forum ,15, 164–170.
[11] Ashour H, El Akkad F, (2001). Phys. Status Solidi (a), 184 ,175.
[12] Mondal, T.K. Chaudhuri and P. Pramanik, (1983).Sol. Energy Mater. 7, 431.
[13] Metin H, Sat F, Erat S, Ari M, (2008). Opto. Adv. Mater. , 10,2622 – 2630.
[14] Apolinar-Iribe A., Acosta-Enrioue M. C., Quevedo-Lopez M. A., Ramirez-BonO R., Castillo S. , (2010).Chalcogenide Letters , 7, 5, 409 – 414.
[15] Kitaev G., Uritskaya A., Mokrushin S., (1965). Russ. J. Phys. Chem. ,39,1101.
[16] Asogwa P.U., (2011).Chalcogenide Letters , 8, 3,163 – 170.
[17] Khallaf H , Oladeji I.O, Chai G, Chow L, (2008) .Thin Solid Films ,516 ,7306–7312.
[18] Amlouk M., Dachraoul M. et al, (1987) .Solar Energy Materials, 15, 453.
[19] Malandrino G., Finocchiaro S T., Rossi P., Dapporto P and Fragal I L., (2005).Chem. Commun. 45 5681.
[20] Kotkata M.F., Masoud A.E. , Mohamed M.B., Mahmoud E.A., (2008).Chalcogenide Letters , 5, 209-217.
[21] Sanap V. B., Pawara B. H.,(2009). Chalcogenide Letters ,6, 415 – 419.
[22] Feitosa A.V, Miranda M. A, Sasaki J. M, Ara´ujo-Silva M. A, (2004).Brazilian Journal of Physics, 34, 656-658.
[23] Pankove J.(1971) Optical Processes in Semiconductors(New York: Dover).
[24] Sahay P.P., Nath R.K., Tiwari S., (2007).Cryst. Res. Technol. 42(3), 275-280.
[25] Grecu R., Popovici E. J., dar M. L., Pascu L., Indrea E.,(2004). Optoelectronics and Advanced Materials , 6, 127 – 132.
[26] Hiie J. , Dedova T., Valdna V., Muska K., (2006) . Thin Solid Films , 512, 443 – 447.
[27] Ezenwa I.A.,Ekpunobi J.,(2010).Pacific Journal of Science and Technology,11,2.435-440.
[28] Milnes A. G. , Feucht D.L.,(1972) , Academic press , New York.
[29] Ismail Raid. A , (2009). Semiconductor Technology and Science ,9,1,.51-54.
[30] Sze S.M., " physics of semiconductor device " ,(1989).John Weily New York.
[31] Ismail Raid. A.,(2006) .Semiconductor Technology and Science ,9, 1,51-54.

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دراسة الخصائص الكهروبصرية لمفرق هجيني نوع CdS-Si محضر بطريقة ترسيب بالحمام الكيميائي

هاني هادي احمد

الخلاصة

تم تحضير كاشف المفرق الهجين نوع CdS-Si بطريقة ترسيب الحمام الكيميائي . والخصائص التركيبة لهذه الأغشية شخصت باستخدام تقنية حيود الأشعة السينية(XRD) .وجد ان أغشية CdS تمتلك تركيبا" بلوريا" مكعبا"(خارصين) وسداسيا" .معدل الحجم الحبيبي 45nm. والخصائص البصرية بينت إن غشاء CdS المرسب يمتلك نفاذية عالية في المنطقة المرئية من الطيف وتصل إلى أكثر من 80% مع فجوة طاقة عريضة 2.44 eV .وتم أيضا" تحليل الخصائص الكهربائية للمفرق الهجين CdS-Si .وأظهرت نتائج خصائص(تيار – جهد) تحت شرط الظلام صفة التقويم والسلوك ألأسي لتيار الانحيازيين الأمامي والعكسي. بينت نتائج قياسات (سعة – جهد) ان المفرق المصنع هو من النوع الحاد وان الجهد البناء الداخلي يساوي الى 1.75 V .الخصائص الكهروبصرية بينت إن الكاشف CdS-Si يمتلك استجابية طيفية جيدة في المنطقة المرئية وتحت الحمراء القريبة من الطيف ويعطي استجابية طيفية عالية مقارنة مع الكواشف السليكونية التقليدية.