Fabrication and Study Characteristics Of CdS/Si Heterojunction Detector by CBD Technique

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Abstract

In the present work, fabrication and characterization detector CdS/Si heterojunction. The CdS thin film depositing on glass substrate and silicon Wafers by chemical bath deposition(CBD) technique. Structure of these films was characterized by X-ray diffraction ,which show that of CdS films deposited have polycrystalline structure cubic(zinc blende) and hexagonal (diamond) and the grain size is 45 nm . The optical properties were studied by transmission spectra where found that for CdS films have highly transmittance in visible region of spectrum and reach to more than 80 % with wide band gap of 2.44 eV is a promising material to be used in photovoltaic devices as solar cells and detectors .Electrical properties of CdS/Si heterojunction have been investigated. The I-V characteristics of 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 1.75V. The optoelectronic characteristics shows the CdS/Si detector has good spectral responsivity in visible and NIR with higher peak responsivity at 800 nm were found 0.26 A/w .The maximum quantum efficiency was found to be (60%) at (800 nm) wavelength.

Keywords: CdS/Si heterojunction detector , chemical bath deposition, , structural and optical properties. I-V characteristics , C-V measurement, optoelectronic characteristics.

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), a typical II–VI semiconductor, 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 of CdS thin films such as spray pyrolysis [6], pulsed laser deposition [7], chemical vapour transport [8], vacuum evaporation [9], electrodeposition [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, and inexpensive 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].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 is presented and analyzed.

Experimental

A CdS film was deposited on both silicon and a cleaned glass substrate at the same conditions by the chemical bath deposition method. A p-type Single – crystal silicon wafers with (100) orientation are used as substrates. They have a resistivity of the order 2 Ω.cm. Prior to the deposition of the CdS film, the silicon wafer was immersed in diluted HF solution and then washed with deionized water to remove the native oxide. The glass substrate was precleaned with a detergent and then cleaned in methanol and acetone for 10 min each by using an ultrasonic cleaner and then cleaned with deionized water and dried. The CdS films was grown on Si and glass substrate by using the cadmium nitrate salt [$Cd(NO_3)_2$.$4H_2O$] in 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-}). Ammonia hydroxide solution (NH_4OH) 25 % was added slowly to adjust pH at 11 .The solution was stirred to ensure homogeneous dissolve about 5 minutes. The bath temperature was kept at 80C° for 1h 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 h.

The thickness of the film was determined with a Mettler Toledo MX5 microbalance using the weighing method with the relation $t=m/(\rho\times A)$ where, m is the mass of the film deposition on the substrate in g; A the area of the deposited film in cm^2 and ρ the density of the deposited material (CdS =4.089 g/cm³) in bulk form[19]. The thickness of the CdS film was found to be approximately 600 ± 5 nm. The X-ray diffraction(XRD) analysis was carried out using X-ray 6000(Shimadzu) diffractometer with Cukα radiation (α-1.541 Å) at 40 kV and 30 mA .The optical transmission spectra were investigated by UV-Visible Spectrophotometer (Cintra 5) GBC-Astrural). Aluminum contacts of 100 nm thickness were formed on the CdS film and the back surface of silicon by thermal evaporation. Figure (1) shows the schematic diagram of a CdS/p-Si heterojunction detector. 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.

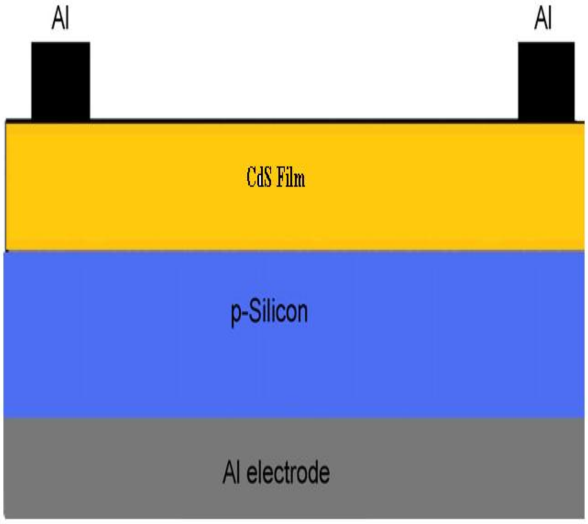

Figure (1): The schematic diagram of the CdS/p-Si heterojunction detector.

Results and discussion

1-X-Ray Diffraction

Figure 2 show 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 polycrystalline in nature. The diffraction peak existed at 2θ = 26.6° corresponding to either the (002) hexagonal or the (111) cubic planes. These values of 2θ and its crystal planes are comparable with standard data from CdS matches well (JCPDS file no .79-0043). Similar results have been observed by CBD as reported in literatures [19,20].

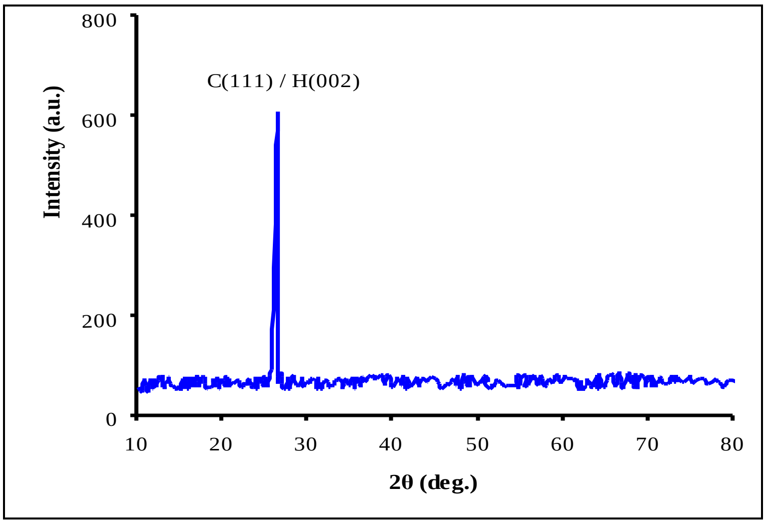

Figure (2): The X-ray diffraction patterns of CdS thin films.

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

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

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 results agree with those of many studies[17,22].

2-Optical Properties

Figure 3 show 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. It is known that CdS is a direct band-gap semiconductor. The direct optical band gap of the CdS film can be calculated by the following relation [23]:

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

Where *hv* 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 *α = (1/d)* ln(1/*T*), where *d* is the thickness of the film and we plotted the curve of $(\alpha h\nu)^2$ versus *hv* of the CdS film, as show in figure 4. The optical band gap of the CdS film was determined from figure 4 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) [24,25,26].

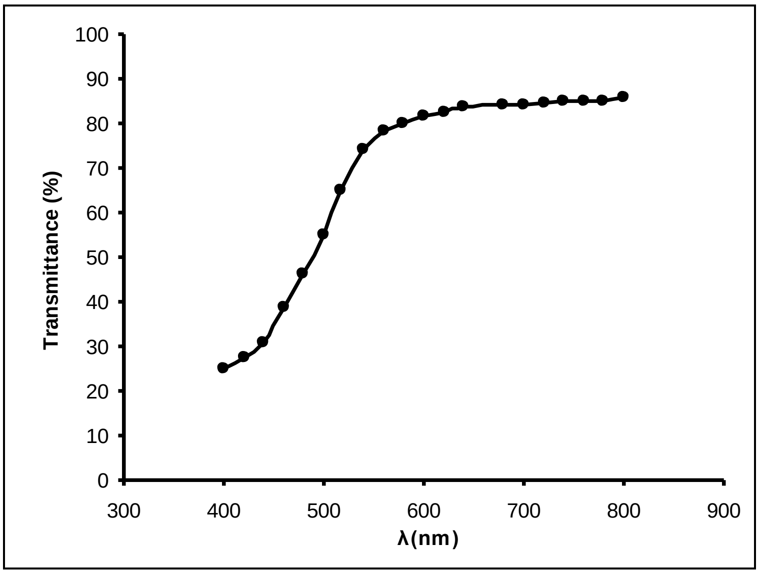

Figure (3): The optical transmission spectra as a function of wavelength of CdS thin films

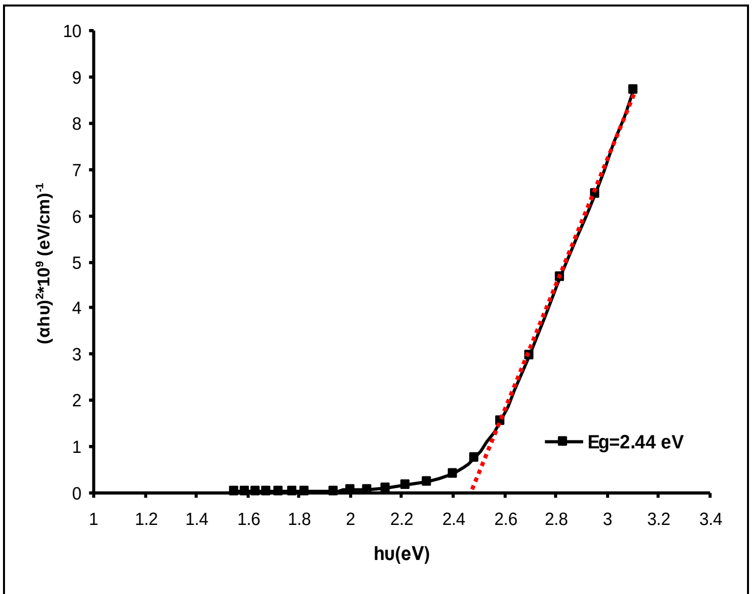

Figure (4): A plots of $(\alpha h\upsilon)^2$ versus (hυ) of CdS thin films.

3-Electrical characteristics of CdS /Si heterojunction

The forward and reverse bias voltage under dark condition of CdS/Si heterojunction is shown in Fig.(5) 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 V_f >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.(6) increasing intensity of light result in the increase in the photocurrent, indicating good linearity characteristics .

The Fig.(7) show C^{-2}-V plot, the decrease a capacitance with increase bias voltage because increase width of the depletion region (increase absorption area).The junction of this heterojunction is abrupt and from Figure the built-in – potential V_{bi} was determined where (C^{-2}=0) was found to be 1.75 Volte.

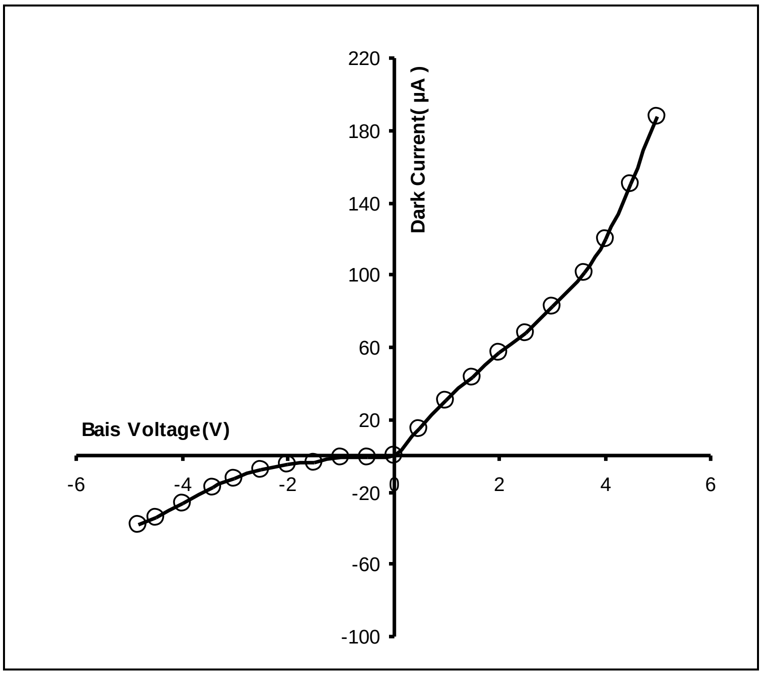

Fig. (5) current-voltage for characteristics CdS/Si heterojunction.

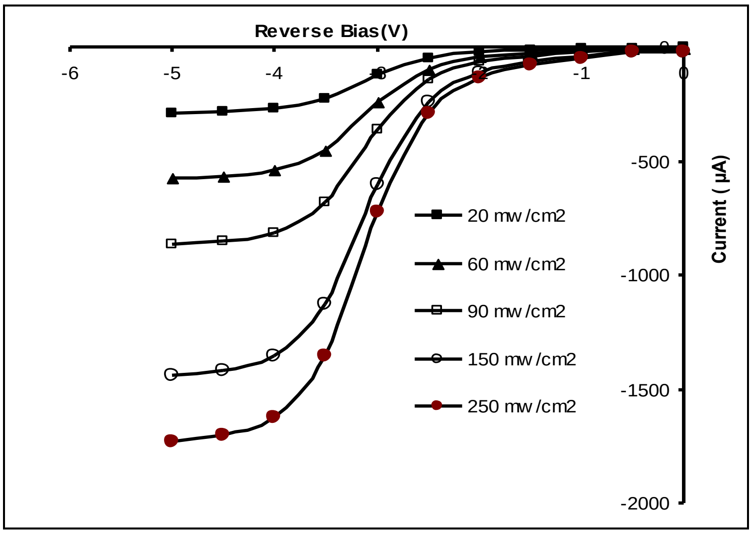

Fig. (6) Current-voltage in illumination condition for characteristics CdS/Si heterojunction.

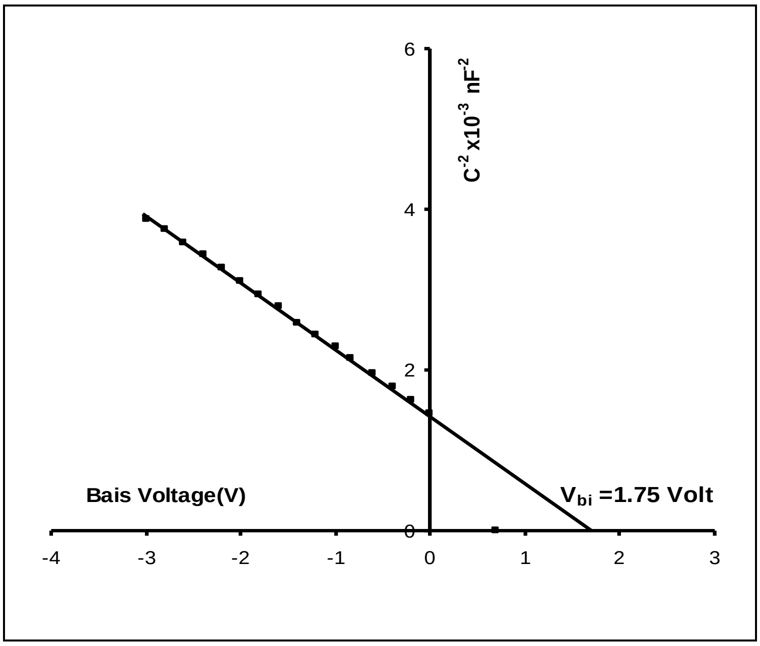

Fig.(7) C^{-2} versus Bias voltage for characteristics CdS/Si heterojunction.

4- Optoelectronic Characteristics of CdS /Si Detector

The responsivity $\Re_\lambda$ as function of wavelength at range spectral (400-1000)nm of the detector at 2 V reverse bias is depicted in Fig. 6. The responsivity can be calculated from the following relationship[28]:

$$\Re_\lambda = \frac{I_{ph}}{P_{inc}} (A/W) \ldots\ldots\ldots(3)$$

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

From the Fig. 6 we show two peaks, first peak at region 550±20 nm this peak due to absorb of light in CdS through band-toband absorption while second region at 800±20 nm which due to the Si band gap[29] .The maximum value of responsivity was (0.26A/w) at λ=800nm.The CdS/Si has high responsivity compared with other hetrojunction such as Bi_2O_3/Si [30]& little than Cu_2O/Si [1] .

Fig. (9) shown quantum efficiency as function of wavelength we have peak quantum efficiency 60% at wavelength 800 nm.

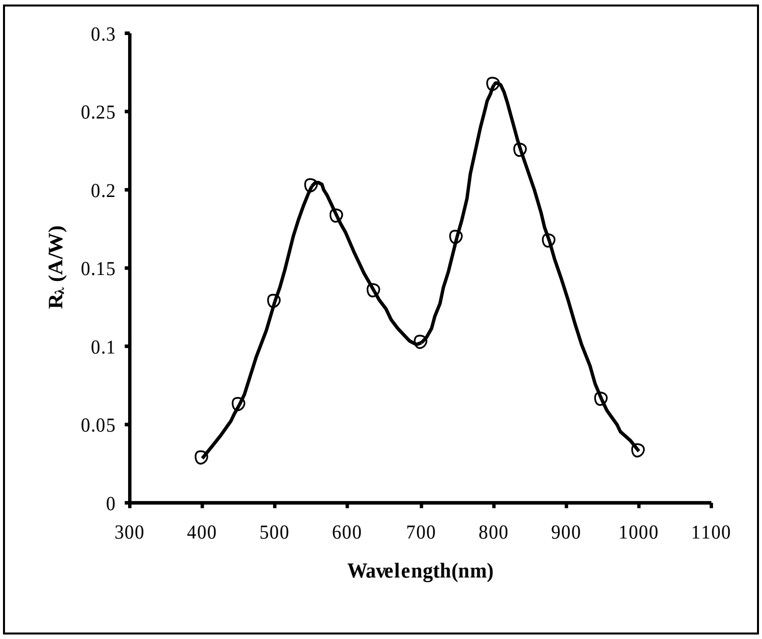

Fig. (8) responsivity as a function of the wavelength of CdS /Si Detector.

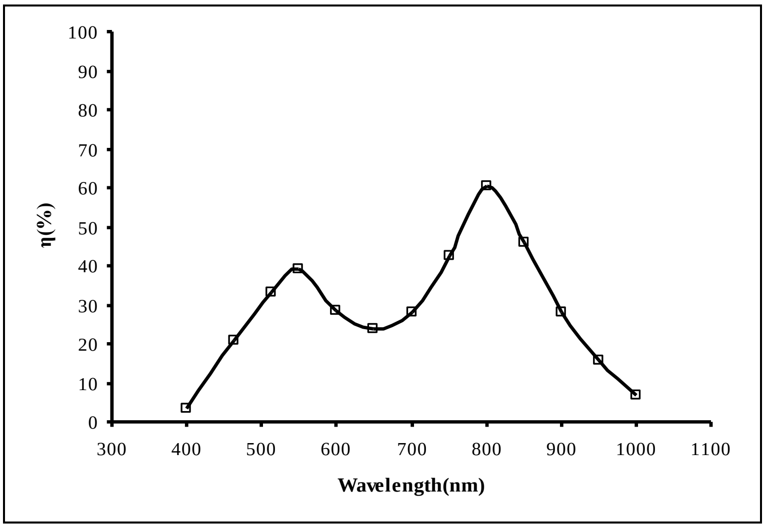

Fig. (9) quantum efficiency as a function of wavelength of CdS /Si Detector.

Conclusions

1- CdS/Si can be prepared by chemical bath deposition technique .

2- The XRD measurements indicate that the structure of the CdS thin films is the (002) hexagonal or the (111) cubic planes cubic(zinc blende).

3- The CdS films has flat surface, a high average transmittance over 80% in the visible region with presence wide band gap of 2.44 eV is a promising material to be used in photovoltaic devices, solar cells and detectors.

4- CdS/Si heterojunction is abrupt type.

5- CdS/Si has two peaks first peak at region 550±20nm this peak due to absorb of light in CdO through band-to-band absorption while second region at 800±20 nm which due to the Si bandgap , responsivisty increase with apply bias voltage .

6- maximum quantum efficiency is 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).J.Appl. Phys. Lett. 82, 571.

[3] Didden, H.Battjes,R.Machunze,B.Dam, R.Van de Krol,(2011).J.Appl. Physics ,110,3,033717(1-7) .

[4] Bugelman M. ,Nollet P.,(2005) .J.Solid State Ionics, 176 ,2171.

[5] Pradhan B. , Pal A.,(2004).J.Sol. Energy Mater. Sol. Cells,81, 469.

[6] Shadia J. Ikhmayies , Riyad N. Ahmad-Bitar,(210). 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).J.Appl. Phys. Lett. **52** 1095

[8] Birkmire R.W., Mc Candless B.E. , Hegedus S.S., (1992).J.Sol. Energy ,12, 45 .

[9] Mahmoud S.A, Ibrahim A.A. , Ismail Raid. A., (2000).J.Thin Solid Films, 372, 144 .

[10] Morris G. C., Tottszer A. , Das S. K. (1991) . J.Mater. Forum **,15,** 164–170.

[11] Ashour H., El Akkad F., (2001). J.Phys. Status Solidi (a), 184 ,175.

[12] Mondal, T.K. Chaudhuri , Pramanik P., (1983).J.Sol. Energy Mater. 7, 431.

[13] Metin H, Sat F, Erat S, Ari M, (2008).J. Opto. Adv. Mater. , 10,2622 – 2630.

[14] Apolinar-Iribe A., Acosta-Enrioue M. C., Quevedo-Lopez M. A., Ramirez-BonO R., Castillo S. , (2010).J. 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).J.Chalcogenide Letters , 8, 3,163 – 170.

[17] Khallaf H , Oladeji I.O, Chai G, Chow L, (2008) .J.Thin Solid Films ,516 ,7306–7312.

[18] Amlouk M., Dachraoul M. et al, (1987) .J.Solar Energy Materials, 15, 453.

[19] Malandrino G., Finocchiaro S T., Rossi P., Dapporto P and Fragal I L., (2005) J.Chem. Commun. 45, 5681.

[20] Kotkata M.F., Masoud A.E. , Mohamed M.B., Mahmoud E.A., (2008).J.Chalcogenide Letters , 5, 209-217.

[21] Sanap V. B., Pawara B. H.,(2009). J.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] Sanap V. B, Pawar B. H,(2010).J.Chalcogenide Letters, 7, 227-231.

[24] Grecu R, Popovici E. J, dar M. L, Pascu L, Indrea E,(2004). Journal of Optoelectronics and Advanced Materials , 6, 127 – 132.

[25] Hiie J. , Dedova T., Valdna V., Muska K., Thin Solid Films , (2006) .511 – 512, 443 – 447.
[26] Ezenwa I.A.,Ekpunobi J.,(2010).Pacific Journal of Science and Technology,11(2):435-440.
[27] Milnes A. G. , Feucht D.L.,(1972) , Academic press , New York.
[28] Ismail Raid. A, (2009). J. semiconductor technology and science ,9,1,.51-54.
[29] Sze S.M., " physics of semiconductor device " ,(1989).John Weily New York.
[30] Ismail Raid. A.,(2006) .J. semiconductor technology and science, 6, 2,119-123.

تصنيع ودراسة خصائص كاشف المفرق الهجين CdS/Si بتقنية ترسيب بالحمام الكيماوي

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الملخص

في هذا البحث تم تصنيع ودراسة خصائص كاشف المفرق الهجين نوع CdS/Si . إذا تم ترسيب غشاءCdS على أرضيات زجاجية و شرائح سليكونية بتقنية ترسيب الحمام الكيميائي(CBD). الخواص التركيبة لهذه الأغشية شخصت باستخدام تقنية حيود الأشعة السينية(XRD) حيث بينت ان غشاءCdS يمتلك تركيبا" بلوريا" مكعبا" (خارصين) وسداسيا"(ماس) ومعدل الحجم الحبيبي nm(45). الخواص البصرية درست باستخدام طيف النفاذية،حيث وجد إن غشاء CdS المرسب يمتلك نفاذية عالية في المنطقة المرئية من الطيف وتصل إلى أكثر من 80% مع فجوة طاقة عريضة 2.44eV التي تسمح للمادة في الاستخدام في الأجهزة الفوتوفولتائية كالخلايا الشمسية والكواشف. تم أيضا" تحليل الخصائص الكهربائية للمفرق الهجين CdS/Si . أظهرت 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(abrupt) وان جهد البناء الداخلي يساويV 1.75. الخصائص الكهروبصرية بينت إن الكاشف CdS/Si يمتلك استجابية طيفية جيدة في المدى المرئي وتحت الحمراء القريبة من الطيف مع أعلى قمة للاستجابية عند الطول ألموجي800nm وجدت(0.26A/w).كما وجد إن أقصى كفاءة كمية كانت(60%) عند الطول ألموجي 800 nm .