Influence of doping concentration on the main parameters of CdSe:Cu photoconductor detector

E.M.Al-Fwade*, S.K.J.Al-Ani ,Th.K.Al-Ani***

* Physics Dept. , College of Science , Baghdad University , Iraq
** Physics Dept. , College of Science , Sanaa University , Al-Yemen

Abstract

The photonconductor detectors CdSe:Cu was fabricated as a thin film of (1 μm) in thickness using vacuum evaporation technique. doping with copper was made using vacuum annealing at 350^{o}C under argon atmosphere . The spectral responsivity and spectral detectivity of the detector were determined as a function of incident wavelength on the sample. A remarkable improvement in performance was absorbed for the specimen, which doping with (1-5 wt%) Cu.

The spectral response increases with increasing of wavelength for incident radiation to maximum value, after that , it reduced sharply . There is a shifting for peak responsivity indirect of higher wavelength. The detectivity was increased with doping but its decreased as the concentration increases. The value of detectivity, which obtained on it , is higher than early published value.

Key words
Detectors , Doping , wavelength

Article info
Received: Dec. 2004
Accepted: Jan. 2005
Published: Dec. 2011

تأثير نسب التشويب على معلمات الكاشف الكهروضوئي CdSe:Cu

ايمان مزهر الفؤادي* ، سلوان كمال جميل العاني ، ذكرى قاسم العاني***

*جامعة بغداد –كلية العلوم – قسم الفيزياء
** اليمن - جامعة صنعاء- كلية العلوم- قسم الفيزياء

الخلاصة:

تم تحضير الكاشف الكهروضوئي CdSe:Cu كغشاء رقيق بسمك (1μm) باستخدام تقنية التبخير الفراغي وتم تشويبه بالنحاس باستخدام التلدين بدرجة ٣٥٠ درجة سليزية تحت ضغط الاركون . تم تحديد الاستجابة الكشفية والطيفية للكاشف كدالة للطول الموجي الساقط على النموذج .اعلى كفاءة للامتصاص عندما طعم النموذج بنسبة 5-1) wt%) من النحاس .

الاستجابة الطيفية ازدادت مع زيادة الطول الموجي لاقصى قيمة وبعد ذلك قلت بصورة حادة وكان هناك انحراف في قمة الاستجابة المباشرة عند اعلى طول موجي . الاستجابة الكشفية ازدادت مع زيادة التشويب ولكن قلت مع زيادة التركيز . القيمة التي تم الحصول عليها للكشف كانت اعلى من القيمة المنشورة .

Introduction

Infrared detectors are classified into two categories – thermal models and quantum models. A thermal detector uses the energy of the infrared beam as a heat , while the quantum detector offers a higher detection [1] .

The performance of infrared detectors is always related to the properties of the corresponding materials .

It is well known that cadmium selenide (CdSe) belong to II-VI compound semiconductors find increasing

applications in photoconductive and photovoltaic detectors and solid state devices . The use of CdSe as a photoconductor provides a detector faster response than CdS . The performances of high quality CdSe thin films devices seem to depend on the preparation condition and other related treatments . The oproelectronic properties of CdSe detector depend on the method of preparation and sensitization .

Furthermore , morphology of CdSe or CdSe doped films affect appreciably the optical and the detector characteristics such as photoconducting , gain quantum efficiency , resposivity , detectivity and response . Impurity doped CdSe crystals were found to have new quasiline impurity photoconductivity spectra due to localized positions of impurity levels above the valance band and below the conduction band of CdSe [2] . A conclusion is reached concerning the existence of compensated donor and acceptor defects in the as deposited state [3] .

The Cu atoms posses a trapping cross section for holes which is relatively grater than that for electrons ($\sigma_P / \sigma_n \sim 10^5$) which clearly incidates that the Cu centers acts as a photoconductivity sensitizing center in a similar semiconductor CdS [4] .

The noise equivalent power (NEP) expressing a particular set of measurement conditions may be written as follows :

$$NEP = PA/(S/N) \quad \text{----------(1)}$$

Where S and N , represent signal and noise under the condition of measurement the detector area (A) and P is the radiant power density which reaches the detector from the blackbody . the reciprocal of NEP was represent the detectivity (in reciprocal watts) , and its often specified in order to make possible comparison among detectors , detectivity is often normalized to an amplifier band width of (1Hz) and a detector area of (1 cm^2) , this yields the parameter specific detectivity (D-star) D* [4] .

Detector performance is typically specified by its D* , which takes into account spectral response , detector area , electrical band width , chopping frequency , operating temperature , optical collection angle and the strength of the incident signal [14] .

The purpose of our work is to study influence of doping concentration on the spectral response and the detectivity of CdSe:Cu photoconductive detector .

1- Basic Consideration

To point out the influence of the manorial parameters on the detector performance we applied the definitions of the spectral resopnsivity and spectral detectivity for CdSe:Cu(PC) detector at room temperature .

The spectral responsivity R_λ [5] is given by :

$$R_\lambda = \lambda \tau_n P_d^{1/2} / hcwt^{3/2} \mu_n n_o^{3/2} \quad \text{----------(2)}$$

Where λ is the wavelength (either the cut- off) or the peak value , τ_n and μ_n the electron life time and mobility , respectively , e is the electron charge , n is the free electron concentration , h is the blank constant , c is the speed of light , P_d is the power dissipation per unit area of the device (density) , w and t the width and thickness sample , respectively . The data were analyzed with the following equation :

$$R_\lambda = I_{ph}/P_o \quad \text{or} \quad V_{ph}/P_o \text{---------(3)}$$

Where I_{ph} is the photocurrent and P_o the corresponding emitting power of the source [6,12] and it measure in Amp/Watt .

The detectivity (D*) is the signal to noise ratio produced with unit radiant flux incident on the detector , or also defined as the reciprocal of the noise equivalent power (NEP) [7 , 12 , 13] .

$$D^* = (q\lambda\eta/2hc)[R_D A/K_B T]^{1/2} \text{ ------(4)}$$

Where η is quantum efficiency , R_D is the Dynamic resistance . Also we can wrote detectivity with the following relation [8] :

$$D^* = (\lambda\eta/2hc)[qA/I_s]^{1/2} \text{ ---------(5)}$$

Where I_s was represent the saturation current at reverses bias , the dectivity can wrote in terms the spectral responsivity with the equation [9 , 10] :

$$D^*=R_\lambda(A\Delta f)^{1/2}/I_n \text{ ----------(6)}$$

Where Δf is the frequency bands width , I_n is the noise current , R_λ is the spectral resposivity as a function of wavelength . the noise current and dark current which associated with this equation :

$$I_n=(2qI_d\Delta f)1/2 \text{ ----------(7)}$$

The detectivity is depend on the associated to detection processes and on the wavelength of incident radiation [11] , and it measured in (cm. $Hz^{1/2}$/watt) .

2- Experimental details

Cadmium Selenide as a thin film of (1 μm) in thickness was deposited on glasses substrate (7.6x6.2cm) using Balzers evaporation unit . High purity 99.99% Aluminum was deposited on CdSe film as ohmic contacts . Copper atoms with different weight percent were introduced into CdSe lattice by dipping in CuCl solusion complemented by annealing vacuum furnace and flowing argon gas .

The photocurrent and spectral response were measured by detector test system DSR-500 supplied by Optoelectronic Laboratories .

3- Result and Discussions

4-1 Spectral response

The doping of CdS films prepared by this method showed similar characteristic as CdSe single crystal . The spectral response has been measured as a function of wavelength for the range (0.4-0.925 μ m) as shown in Fig.(1) .

We can see from this figure that maximum peak responsivity was laying at the wavelength (0.68 , 0.69 μm) for (1,2 Wt%) Cu concentration . The spectral response is increased with increasing of wavelength for incident radiation to maximum value at wavelength λ_{max} after that , its decrease to minimum value , this attributed to decrease of absorption coefficient , which caused by decrease the absorption , this attributed to that the incident energy on the semiconductor is less than the energy gap . This leads to decrease in responsivity [6] . Also we can see that there is a shifting for peak resposivity toward of higher wavelength from (0.65 μ m) for CdSe (pure) [15] to (0.68 , 0.69 μ m) for (1 &2 Wt%) Cu concentration , these attributed to the Cu impurity levels which lie at the energy gap and need small energy to transport the carrier for these level to the conduction band . The small peaks at this figure are referees to these levels , this result are in agreement with the reference [15-18] . The concentration (3 & 5)% were given remember early at reference [19] and figure (2) was shown it

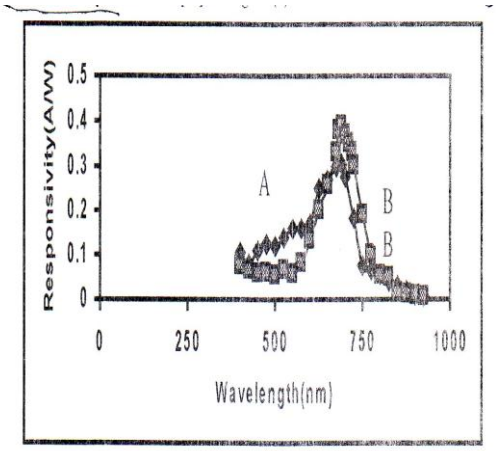

Fig. (1) : The variation of responsivity with wavelength for CdSe : Cu detector for Cu concentration [A(1)% , B(2)%)]

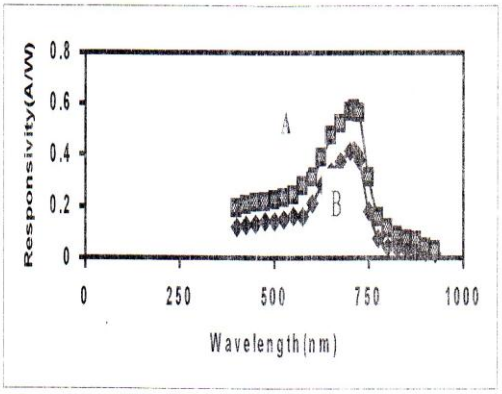

Fig. (2) : The variation of responsivity with wavelength for CdSe : Cu detector for Cu concentration [A(3)% , B(5)%)]

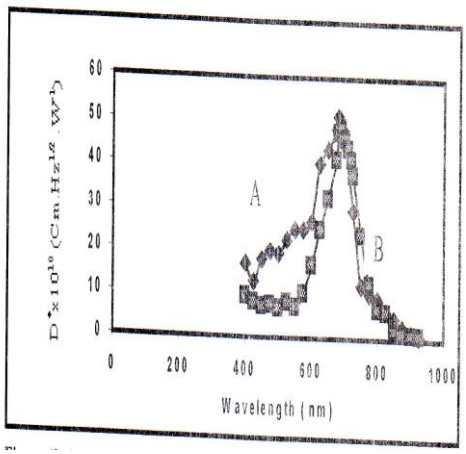

Fig. (3-a) : Varying the detectivity as a function of wavelength for CdSe : Cu detector [A(1)% , B(2)%)]

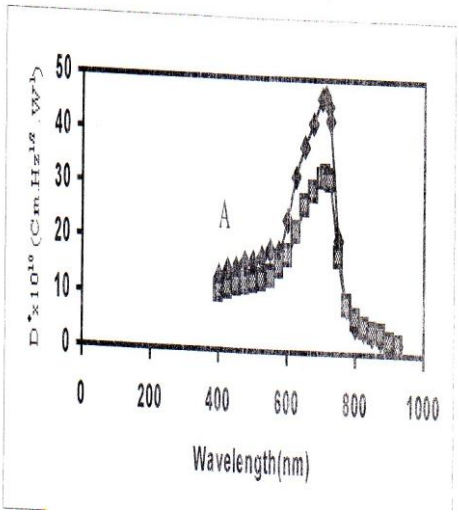

Fig. (3-b) : Varying the detectivity as a function of wavelength for CdSe : Cu detector [A(3)% , B(5)%)]

4-2 Detectivity

By using equation (5) , we can calculate the D* for CdSe: Cu films at concentration (1,2,3&5) % at room temperature as shown in fig.(3) . We can see from this figure dependence of D* on wavelength and its increases with increasing wavelength up to the highest detectivity at near the cut off , after that , it reduced sharply and the reason for increment is the same as the spectral resposivity .

The maximum value of D* occurs at λ = (0.68 , 0.69, 0.71 , 0.81 μ m) was equal to (51.3 x 10^{10}, 48.7 x 10^{10}, 47.07 x 10^{10}, 32.19 x 10^{10}) cm.$Hz^{1/2}$.W^{-1} for Cu concentration (1,2,3,5)Wt% . Also we can see from this figure that the D* slightly decreases with increases of Cu concentration and this agreement with the reference [5,13] , where they see that the detectivity was increases with doping but its decreases as the concentration increases . The reference [20] found that the detectivity for CdSe (pure) is about 4.1X10^{10} and the increasing in this value which we get on it is attributed to the existence of Cu impurity in CdSe .

4- Conclusions

Cu- doped CdSe films formed by vacuum evaporation of 1 μm in thickness with Cu concentration of (1,2,3&5)% . The spectral responsivity and spectral detectivity of the detector were determined as a function of incident wavelength on the detector . We found that maximum peak responsivity and at the spectral response is increased with increasing of wavelength for incident radiation to maximum value , after that , it reduced sharply . We found that there was shift for peak responsivity of higher wavelength from (0.65 μm) for (CdSe

(pure) [15] to (0.68 , 0.69 μ m) for (1&2Wt%) Cu concentration . There are small peaks at the spectrum of responsivity which referees to Cu levels in CdSe . We are conclude from this study dependce of D* on wavelength . we are concluding that detectivity was increased with doping but its decreased as the concentration increase . The value of detectivity , which obtained on it , is higher than the early published value .

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